Amendment 2 (01/2020)
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 the following Chapter 20 for the existing reserved Chapter 20:

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 this Part.

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:**

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

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:

$$NTE_{pollutant} = CF_{pollutant} \times Limit$$

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.

3.1.3.3. 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 (8^0 C) 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 stops 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 shift indicator) [5]	#	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 $ppmC_1$ per test	≤2% of reading or ≤10 $ppmC_1$ 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	$\lvert \chi_{min} \times (a_1 - 1) + a_0 \rvert$	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) [$ppmC_1$]

$C_{m,d}$ = Measured HC concentration in Step (iv) [ppmC1]

The oxygen interference E_{O2} shall be less than ±1.5% for all required oxygen interference check gases.

(vii) 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.

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

(ix) Conversion Efficiency of the Non-methane Cutter (NMC)

4.3.4. 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 vapor 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 analyse.

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 ≤ 12 s with a rise time of ≤ 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.

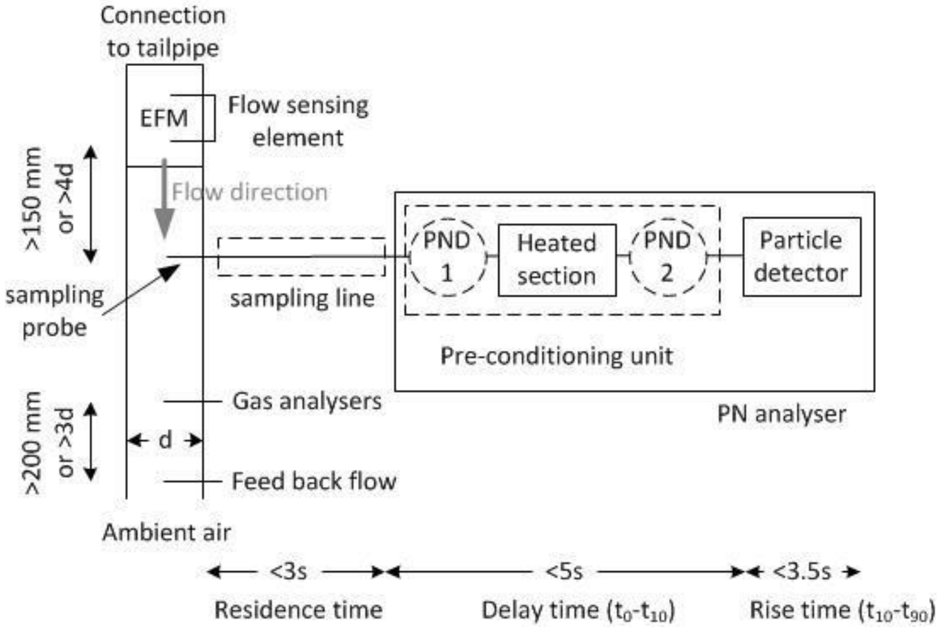


Figure 1
Example of a PN Analyser Setup:
Dotted lines depict optional parts.
EFM = Exhaust mass Flow Meter,
d = inner diameter,
PND = Particle Number Diluter.

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 d50=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/m3.
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)
ρ_e	Density of the exhaust
ρ_{gas}	Density of the exhaust component "gas"
λ	Excess air ratio
λ_i	Instantaneous excess air ratio
A/F_{st}	Stoichiometric air-to-fuel ratio [kg/kg]
°C	Degrees centigrade
C_{CH4}	Concentration of methane
C_{CO}	Dry CO concentration [%]
C_{CO2}	Dry CO_2 concentration [%]
C_{dry}	Dry concentration of a pollutant in ppm or per cent volume

$C_{gas,i}$	Instantaneous concentration of the exhaust component "gas" [ppm]
C_{HCw}	Wet HC concentration [ppm]
$C_{HC(w/NMC)}$	HC concentration with CH_4 or C_2H_6 flowing through the NMC [ppmC_1]
$C_{HC(w/oNMC)}$	HC concentration with CH_4 or C_2H_6 bypassing the NMC [ppmC_1]
$C_{i,c}$	Time-corrected concentration of component i [ppm]
$C_{i,r}$	Concentration of component i [ppm] in the exhaust
C_{NMHC}	Concentration of non-methane hydrocarbons
C_{wet}	Wet concentration of a pollutant in ppm or per cent volume
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:

$$k_w = \left(\frac{1}{1 + a \times 0.005 \times \left(C_{co_2} + C_{co}\right)} - k_{w1}\right) \times 1.008$$

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:

$$C_{CH4} = \frac{C_{HC\left(\frac{w}{oNMHC}\right)} \times (1 - E_M) - C_{HC\left(\frac{w}{NMC}\right)}}{(E_E - E_M)}$$

$$C_{NMHC} = \frac{C_{HC\left(\frac{w}{NMC}\right)} - C_{HC\left(\frac{w}{oNMC}\right)} \times (1 - E_E}{r_h \times (E_E - E_M)}$$

In method (b), the concentration of CH4 and NMHC shall be calculated as follows:

$$C_{CH4} = \frac{C_{HC\left(\frac{w}{ONMC}\right)} \times r_h \times (1 - E_M) - C_{HC\left(\frac{w}{ONMC}\right)} \times (1 - E_E)}{r_h \times (E_E - E_M)}$$

$$C_{NMHC} = \frac{C_{HC\left(\frac{w}{ONMC}\right)} \times (1 - E_M) - C_{HC\left(\frac{w}{NMC}\right)} \times r_h \times (1 - E_M)}{(E_E - E_M)}$$

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:

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

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

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 β = 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/m³]	Component or pollutant i					
		NO_X	CO	HC	CO_2	O_2	CH_4
		ρgas [kg/m³]					
		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
$\leq$	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]
$\overline{v_j}$	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.

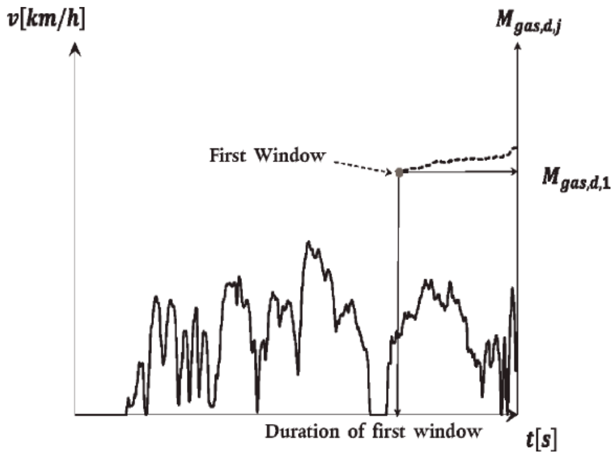


Figure 1
Vehicle Speed Versus Time – Vehicle Averaged Emissions Versus Time, tarting from the First Averaging Window

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 $\bar{v}_j$

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):

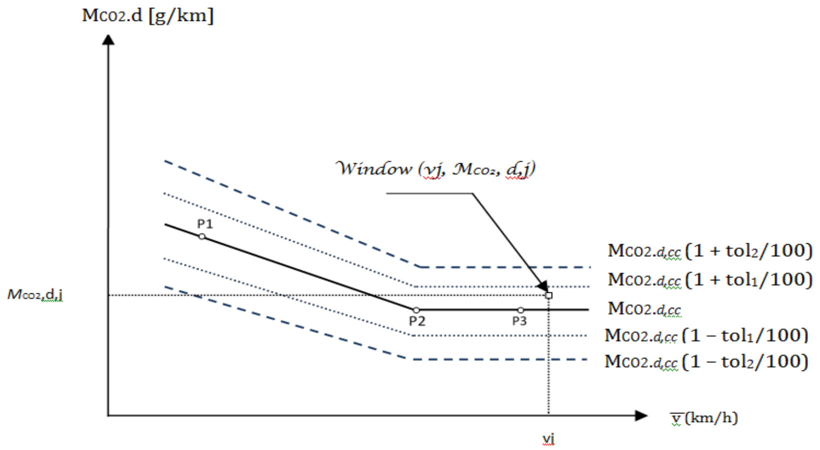
$$M_{CO_2,d,cc}(\bar{v}) = a_1\bar{v} + b_1$$

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 $\overline{v}_j$ 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 $\overline{v}_j$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

$\overline{v}_j$greater than or equal to 55 km/h and smaller than 120 km/h for M category vehicles & $\overline{v}_j$ greater than or equal to 55km/h and smaller than 80km/h for N1 category vehicles.

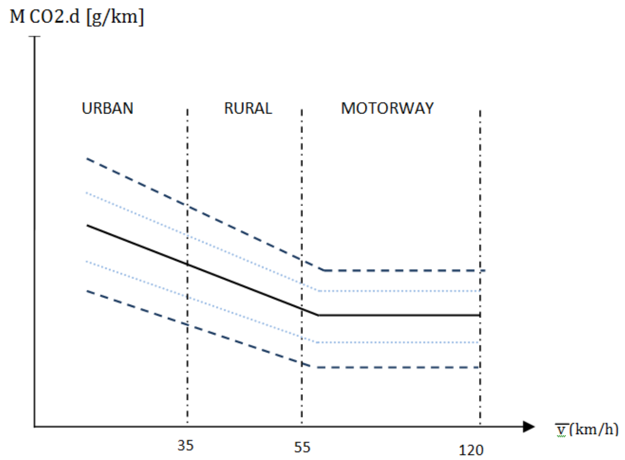


Figure 4

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

$$M_{CO2,d,cc}(\overline{v_j}).\left(1 - \frac{tol_1}{100}\right) \le M_{CO2,dj} \le M_{CO_2,d,cc}\,(\overline{v_1}).\left(1 + \frac{tol_1}{100}\right)$$

Then w_j=1

If

$$M_{CO2,d,cc}(\overline{v_j}).\left(1 + \frac{tol_1}{100}\right) < M_{CO2,dj} \le M_{CO_2,d,cc}\,(\overline{v_j}).\left(1 + \frac{tol_2}{100}\right)$$

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:

$$h_j = 100 \cdot \frac{M_{CO2,dj} - M_{CO2,dcc}(\overline{v_j})}{M_{CO2,dcc}(\overline{v_j})}$$

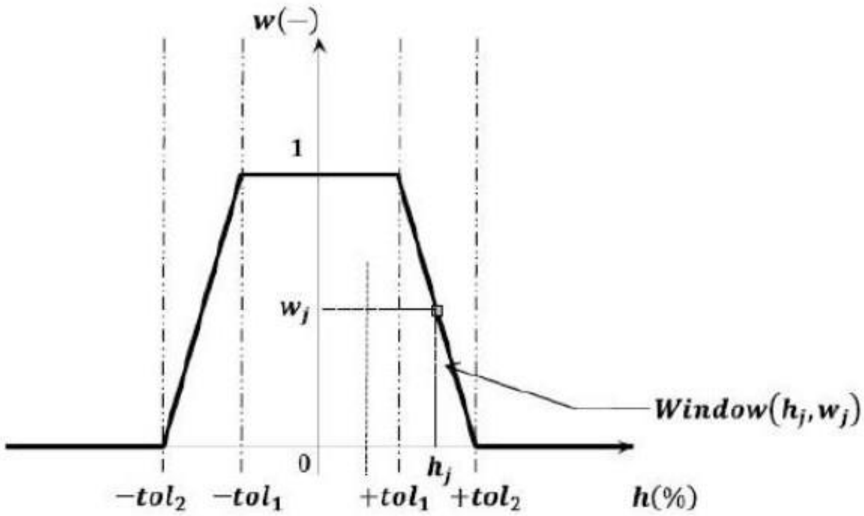


Figure 5
Averaging Window Weighing Function

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

$$\overline{h_t} = \frac{f_u \overline{h_u} + f_r \overline{h_r} + f_m \overline{h_m}}{f_u + f_r + f_m}$$

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).

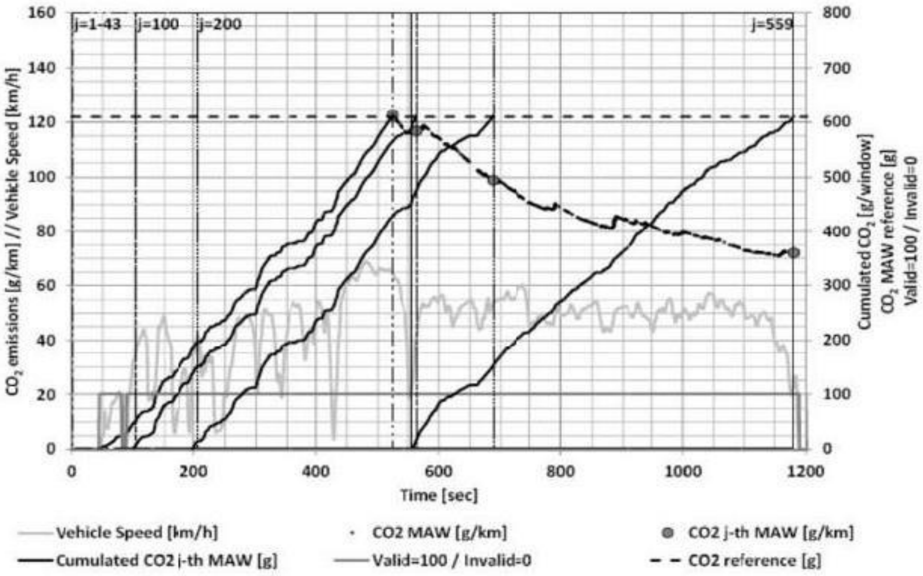


Figure 6

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

$$a_1 = \frac{91.49 - 138.72}{59.3 - 19.3} = -\frac{47.23}{40.3} = -1.172$$

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:

$$M_{CO2,d,45} = 145.86 \text{ g / km}$$
$$\overline{v_{45}} = 26.47\ km/h$$

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

For the characteristic curve:

$$M_{CO2,d,cc}(\overline{V_{45}}) = a_1\overline{v_{45}} + b_1 = -1.172 \times 26.45 + 160.987 = 129.964$$

Verification of:

$$M_{CO2,d,cc}(\overline{v_j}).\left(1 - \frac{tol_1}{100}\right) \leq M_{CO2,d,j} < M_{CO2,d,cc}(\overline{v_j}).\left(1 + \frac{tol_1}{100}\right)$$

$$M_{CO2,d,cc}(\overline{v_{45}}).\left(1 - \frac{tol_1}{100}\right) \leq M_{CO2,d,45} < M_{CO2,d,cc}(\overline{v_{45}}).\left(1 + \frac{tol_1}{100}\right)$$

$$129.964 \times (1 - 25/100) \leq 145.86 \leq 129.964 \times (1 + 25/100)$$

$$97.473 \leq 145.86 \leq 162.455$$

Leads to: $w_{45} = 1$

For window #5074:

$$M_{CO2,d,5074} = 141.84 \text{ g/km}$$

$$\overline{v_{5074}} = 52.44 \text{ km/h}$$

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:

$$M_{CO2,d,cc}(\bar{v}_{5152}) =$$

$$M_{CO_{2},d,CC}(\bar{v}_{5152}) = a_1\ \bar{v}_{5152} + b_1 = -1.172 \times 52.44 + 160.987 = 99.527\ g/km$$

Verification of:

$$M_{CO2,d,cc}(\bar{v}_{5152}) \cdot \left(1+\frac{tol_1}{100}\right) \leq\ M_{CO2,d,cc,5074} \leq\ M_{CO2,d,cc}(\bar{v}_{5152}) \cdot \left(1+\frac{tol_2}{100}\right)$$

$$99.527 \times (1+25/100) \leq 141.84 \leq 99.527 \times (1+50/100)$$

$$124.4091 \leq 141.84 \leq 149.291$$

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]**	$M_{CO2}(t_{2},j) - M_{CO2}(t_{1},j) \geq M_{CO2,ref}$ **[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 10 % 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 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 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·apos)j,k	Actual vehicle speed per positive acceleration greater than $0.1m/s^2$ in time Step j considering the urban, rural and motorway shares [m^2/s^3 or W/kg].
$(v \cdot a_{pos})_{k\_}$ [95]	95th percentile of the product of vehicle speed per positive acceleration greater than $0.1m/s^2$ 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:

a_i 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:

$(v·a)_i$ = 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:

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

where:

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

Δt 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:

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

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:

$$|h(t) - h(t-1)| > \frac{v(t)}{3.6} * \sin 45°$$

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:

$road_{grade,1(d)} = \frac{h_{int}(d+200m) - h_{int}(da)}{(d+200m)}$	
$road_{grade,1(d)} = \frac{h_{int}(d+200m) - h_{int}(d-200m)}{(d+200m)-(d-200m)}$	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 smoot-hing 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 at meters [m]	a	distance of zero
d_e	Cumulative distance travelled until the last discrete way point [m]		

The second smoothing run shall be applied as follows :

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

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

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

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].

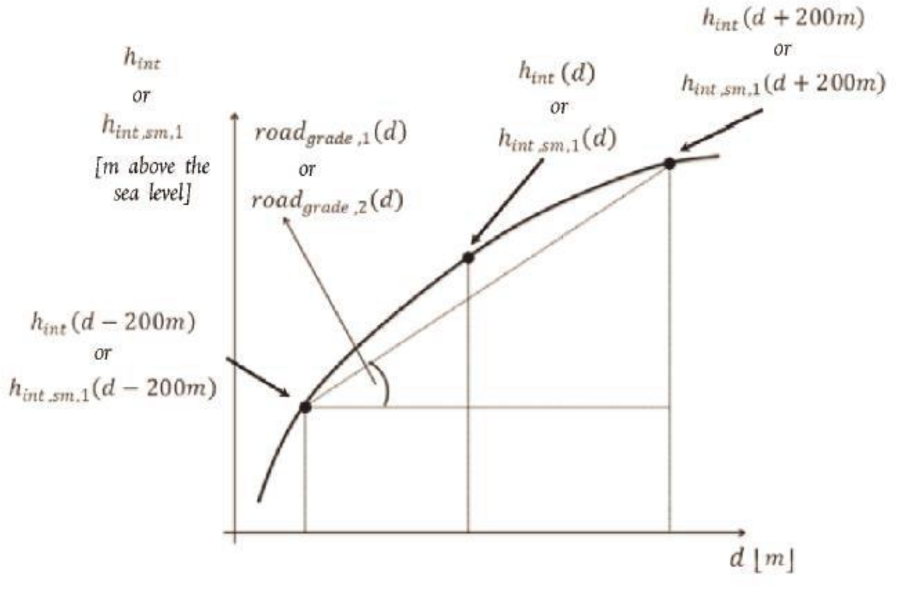


Figure 1 Illustration of the Procedure to Smooth the Interpolated Altitude Signals

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:

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

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

5.2. **Correction of Instantaneous Vehicle Altitude Data**

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

$$|h(t) - h(t-1)| > \left(\frac{v(t)}{3.6} * \sin 45°\right)$$

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:

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

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

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:

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

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

Second smoothing run:

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

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]	$roadgrade_{,1}(d)$ [m/m]	$h_{int,sm,1}(d)$ [m]	$roadgrade_{,2}(d)$ [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

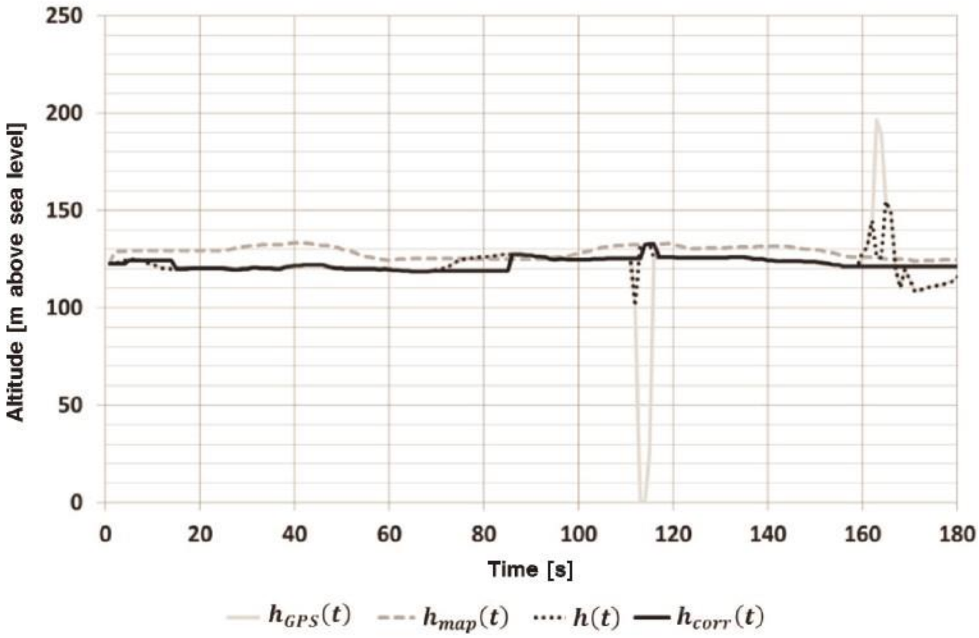


Figure 2
The Effect of Data Verification and Correction – The Altitude Profile Measured by GPS hGPS(t), the Altitude Profile Provide by the Topographic Map h_{map}(t), the Altitude Profile Obtained after the Screening and Principle Verification of Data Quality at a h(t) and the Correction h_{corr}(t)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

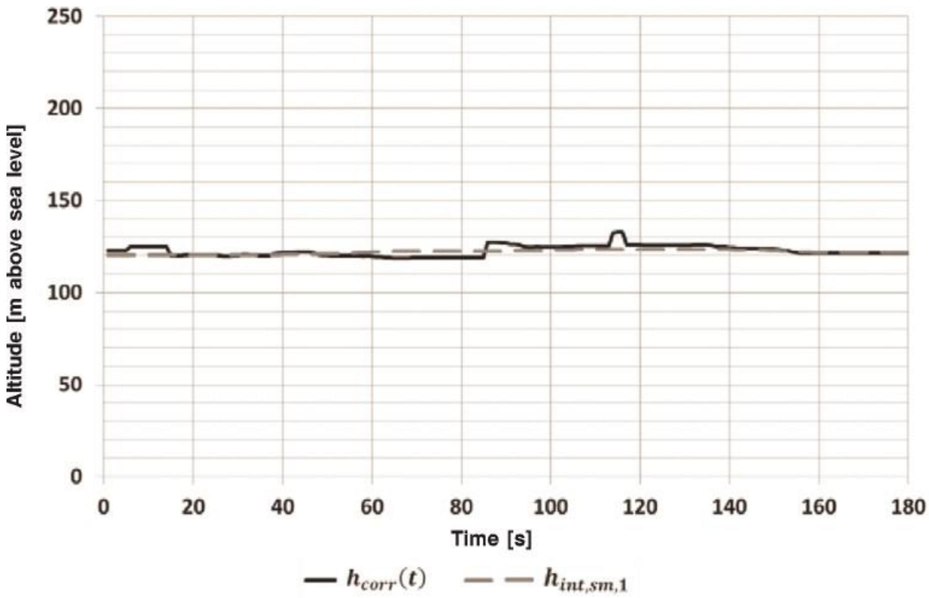


Figure 3
Comparison between the Corrected Altitude Profile h_{corr}(t) and the Smoothed Interpolated Altitude $h_{int,sm,1}$

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]	roadgrade,1(d) [m/m]	$h_{int,sm,1}(d)$ [m]	roadgrade,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 0.1m/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 standardized 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	[F0, F1, F2]

	MIDC	
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 humid ity	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 concentrat ion	Analyser	[ppm]	[(2)]

	NO_X concentration	Analyser	[ppm]	(2)
	NO concentration	Analyser	[ppm]	(2)
	NO_2 concentration	Analyser	[ppm]	(2)
	O_2 concentration	Analyser	[ppm]	(2)
	PN concentration	Analyser	[#/m^3]	(2)
	Exhaust mass flow rate	EFM	[kg/s]	(2)
	Exhaust temperature in the EFM	EFM	[K]	(2)
	Exhaust mass flow 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)
	Percent 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 $\pm tol_1$	
112	Number of urban windows within $\pm tol_1$	
113	Number of rural windows within $\pm tol_1$	
114	Number of motorway windows within $\pm tol_1$	

115	Number of windows within ± 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.

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

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ON BEHALF OF

AUTOMOTIVE INDUSTRY STANDARDS COMMITTEE

UNDER

CENTRAL MOTOR VEHICLES RULES - TECHNICAL STANDING COMMITTEE

SET-UP BY

MINISTRY OF ROAD TRANSPORT & HIGHWAYS

(DEPARTMENT OF ROAD TRANSPORT & HIGHWAYS)

GOVERNMENT OF INDIA

17th January 2020

Amendment 1 (01/2020)
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 6/296, Chapter 1,

Insert following new clauses 2.35 and 2.36 after clause 2.34:

2.35 **"Base Emission Strategy" (hereinafter 'BES')** means an emission strategy that is active throughout the speed and load operating range of the vehicle unless an auxiliary emission strategy is activated

2.36 **"Auxiliary Emission Strategy" (hereinafter 'AES')** means an emission strategy that becomes active and replaces or modifies a BES for a specific purpose and in response to a specific set of ambient or operating conditions and only remains operational as long as those conditions exist.

2.0 Page 8/296, Chapter 1,

Insert following new clause 3.3.10, 3.3.11, 3.3.12 and 3.3.13 after clause 3.3.9:

3.3.10 The use of defeat devices that reduce the effectiveness of emission control systems shall be prohibited. The prohibition shall not apply where:

a) The need for the device is justified in terms of protecting the engine against damage or accident and for safe operation of the vehicle;

b) The device does not function beyond the requirements of engine starting; or

c) The conditions are substantially included in the test procedures for verifying evaporative emissions and average tailpipe emissions.

3.3.11 In order for the Test Agency to be able to assess the proper use of AES, taking into account the prohibition of defeat devices, the manufacturer shall also provide an extended documentation package, as described in Appendix 1 of Chapter 2 to this Part.

3.3.12 The extended documentation package referred to in clause 3.3.11 shall remain strictly confidential. The package shall be identified and dated by the Test Agency and kept by that Test Agency for at least ten years after the approval is granted. The extended documentation package shall be transmitted to the Nodal Agency upon request.

3.3.13 At the request of the manufacturer, the Test agency shall conduct a preliminary assessment of the AES for new vehicle types. In that case, the relevant documentation shall be provided to the Test agency between 2 and 12 months before the start of the type-approval process.

Test Agency shall make a preliminary assessment on the basis of the extended documentation package, as described in Point (b) of Appendix 1 of Chapter 2, provided by the manufacturer. Test agency shall make the assessment in accordance with the methodology described in Appendix 2 of Chapter 2. Test agency may deviate from that methodology in exceptional and duly justified cases.

The preliminary assessment of the AES for new vehicle types shall remain valid for the purposes of type approval for a period of 18 months. That period may extend by a further 12 months if the manufacturer provides to the approval authority proof that no new technologies have become accessible in the market that would change the preliminary assessment of the AES.

A list of AES which were deemed non-acceptable by Test agency shall be compiled and made available to the public by MoRTH.

3.0 Page 39/296, Chapter 2,

Insert following new Appendix 1 and 2 after chapter 2:

Chapter 2: Appendix 1

EXTENDED DOCUMENTATION PACKAGE

1.0 Introduction:

In order for the Test Agency to be able to assess the proper use of AES, taking into account the prohibition of defeat devices, the manufacturer shall provide an extended documentation package.

2.0 Extended Documentation Package:

The extended documentation package shall include the following information on all AES:

2.1 A declaration of the manufacturer that the vehicle does not contain any defeat device not covered by one of the exceptions in Clause 3.3.10 of chapter 1 to this Part

2.2 A description of the engine and the emission control strategies and devices employed, whether software or hardware, and any condition(s) under which the strategies and devices will not operate as they do during testing for TA;

2.3 A declaration of the software versions used to control these AES/BES, including the appropriate checksums of these software versions and instructions to the Test Agency on how to read the checksums; the declaration shall be updated and sent to the Test

Agency that holds this extended documentation package each time there is a new software version that has an impact to the AES/BES;

2.4 Detailed technical reasoning of any AES including a risk assessment estimating the risk with the AES and without it, and information on the following:

2.4.1 Why any of the exception clauses from the defeat device prohibition in Clause 3.3.10 of chapter 1 to this Part apply,

2.4.2 Hardware element(s) that need to be protected by the AES, where applicable;

2.4.3 Proof of sudden and irreparable engine damage that cannot be prevented by regular maintenance and would occur in the absence of the AES, where applicable;

2.4.4 A reasoned explanation on why there is a need to use an AES upon engine start, where applicable;

2.5 A description of the fuel system control logic, timing strategies and switch points during all modes of operation;

2.6 A description of the hierarchical relations among the AES (i.e., when more than one AES can be active concurrently, an indication of which AES is primary in responding, the method by which strategies interact, including data flow diagrams and decision logic and how does the hierarchy assure emissions from all AES are controlled to the lowest practical level;

2.7 A list of parameters which are measured and/or calculated by the AES, along with the purpose of every parameter measured and/or calculated and how each of those parameters relates to engine damage; including the method of calculation and how well these calculated parameters correlate with the true state of the parameter being controlled and any resulting tolerance or factor of safety incorporated into the analysis;

2.8 A list of engine/emission control parameters which are modulated as a function of the measured or calculated parameter(s) and the range of modulation for each engine/emission control parameter; along with the relationship between engine/emission control parameters and measured or calculated parameters

2.9 An evaluation of how the AES will control real-driving emissions to the lowest practical level, including a detailed analysis of the expected increase of total regulated pollutants and CO2 emissions by using the AES, compared to the BES.

2.10 The extended documentation package shall be limited to 100 pages and shall include all the main elements to allow the Test agency to assess the AES. The package may be complemented with annexes and other attached documents, containing additional and complementary elements, if necessary.

The manufacturer shall send a new version of the extended documentation package to the Test agency every time changes are introduced to the AES. The new version shall be limited to the changes and their effect. The new version of the AES shall be evaluated and approved by the type approval authority.

The extended documentation package shall be structured as follows:

3.0 Extended Documentation Package for AES Application No. YYY/OEM

Parts	Paragraph	Point	Explanation
Introduction Document		Introduction letter to Test agency	Reference of the document with the version, the date of issuing the document, signature by the relevant person in the manufacturer organization
		Versioning table	Content of each version modifications: and with part is modified
		Description of the (emission) types concerned	
		Attached documents table	List of all attached documents
		Absence of defeat device declaration	+ signature
Core Document	0	Acronyms/ abbreviations	
	1	GENERAL DESCRIPTION	
	1.1	Engine general presentation	Description of main characteristics: displacement, after treatment.
	1.2	General system architecture	System bloc diagram: list of sensors and actuators, explanation of engine general functions

	1.3	Reading of software and calibration version	E.g. scan-tool explanation	
	2	Base Emission Strategies		
	2.x	BES x	Description of Strategy x	
	2.y	BES y	Description of Strategy y	
	3	Auxiliary Emission Strategies		
	3.0	Presentation of the AESs	Hierarchical relations among AES: description and justification (e.g. safety, reliability, etc.)	
	3.x	AES x	3.x.1	AES justification
			3.x.2	Measured and/or modelled parameters for AES characterization
			3.x.3	Action mode of AES – Parameters used
			3.x.4	Effect of AES on pollutants and CO2
	3.y	AES y	3.y.1 3.y.2 etc.	
100 page limit ends here				
	Annex		List of types covered by this BES-AES: including TA reference, software reference, calibration number, checksums of each version and of each CU (engine and/or after-treatment if any)	
Attached Docum		Technical note for AES justification n° xxx	Risk assessment or justification by testing or example of sudden	

			damage, if any
		Technical note for AES justification n° yyy	
		Test report for specific AES impact quantification	test report of all specific tests done for AES justification, test conditions details, description of the vehicle/date of the tests emission/CO2 impact with/without AES activation

Chapter 2: Appendix 2

METHODOLOGY FOR THE ASSESSMENT OF AES

The assessment of the AES by the type-approval authority shall include at least the following verifications

1.0 The increase of emissions induced by the AES shall be kept at the lowest possible level:

1.1 The increase of total emissions when using an AES shall be kept at the lowest possible level throughout the normal use and life of the vehicles;

2.0 When used to justify 0an AES, the risk of sudden and irreparable damage to the "propulsion energy converter and the drivetrain", shall be appropriately demonstrated and documented, including the following information:

2.1 Proof of catastrophic (i.e. sudden and irreparable) engine damage shall be provided by the man0ufacturer, along with a risk assessment which includes an evaluation of the likelihood of the risk occurring and severity of the possible consequences, including results of tests carried out to this effect;

2.2 Durability and the long-term protection of the engine or components of the emission control system from wear and malfunctioning shall not be considered an acceptable reason to grant an exemption from the defeat device prohibition.

3.0 An adequate technical description shall document why it is necessary to use an AES for the 0safe operation of the vehicle:

3.1 Proof of an increased risk to the safe operation of the vehicle should be provided by the manufacturer along with a risk assessment which includes an evaluation of the likelihood of the risk occurring and severity of the possible consequences, including results of tests carried out to this effect;

4.0 An adequate technical description shall document why it is necessary to use an AES during engine start:

4.1 Proof of the need to use an AES during engine start shall be provided by the manufacturer along with a risk assessment which includes an evaluation of the likelihood of the risk occurring and severity of the possible consequences, including results of tests carried out to this effect.

4.0 Page 69/296, Chapter 3, Table 3

Substitute following Table 3 for existing Table 3:

Table 3

Modified Indian Driving Cycle (MIDC) Extra-urban (Part Two) for the Type I Test

No of Operation	Operation	Phase	Acceleration time ( )	Speed (km)	Duration of each Operation	Duration of each Phase	Cumulative ( )	Gear to be used in case of manual gearbox
1	Idling	1			20	20	20	K1 (*)
2	Acceleration	2	0.83	0-15	5	41	25	1
3	Gear change				2		27	----
4	Acceleration		0.62	15-35	9		36	2
5	Gear change				2		38	----
6	Acceleration		0.52	35-50	8		46	3
7	Gear change				2		48	----
8	Acceleration		0.43	50-70	13		61	4

9	Steady Speed	3		70	50	50	111	5
10	Deceleration	4	-0.69	70-50	8	8	119	4 s 5 + 4 s 4
11	Steady Speed	5		50	69	69	188	4
12	Acceleration	6	0.43	50-70	13	13	201	4
13	Steady Speed	7		70	50	50	251	5
14	Acceleration	8	0.24	70-90	24	24	275	5
15	Steady Speed	9		90	83	83	358	5
16	Deceleration	10	-0.69	90-80	4	22	362	5
17	Deceleration		-1.04	80-50	8		370	5
18	Deceleration		-1.39	50-00	10		380	K5 (*)
19	Idle	11			20	20	400	PM (*)
(*) PM - gearbox in neutral, clutch engaged K1 K2 - first or second gear engaged , clutch disengaged								

5.0 Page 259/296, Chapter 19, clause 10.6.1,

Substitute following text for existing text

(b) The test result shall be multiplied by the Evolution Coefficient (EC) determined as follows:

- The emissions of CO2 will be measured at zero and at ‘x’ km on the first tested vehicle.

6.0 Page 222/296, Chapter 17, clause 3.1.2.5.5, third paragraph

Substitute following text for existing text

In the case of testing according to clause 3.1.2.5.2.2., of this Chapter the test result of each combined cycle run (M1ia), multiplied by the appropriate deterioration and to apply multiplicative or additive Ki factors, shall be less than the limits prescribed in clause 5.3.1.4. of Chapter 1 to this Part. For the purposes of the calculation in clause 3.1.4 of this Chapter M1i shall be defined as:

$$M_{1i} = \frac{1}{N}\sum_{a=1}^{N} M_{1ia}$$

Where:

i: pollutant

a: cycle

7.0 Page 218/296, Chapter 16,

Add following new clause 11.0 after clause 10.0.

11.0 Alternate requirement for Warning messages*

As an alternate to display the warning messages as specified in this chapter, manufacturer may / opt to meet the requirements as specified below.

- A tell-tale and
- Error code to indicate the waning messages according the Table 1 below

If warning codes are used instead of warning messages as required in this chapter, text message will be printed in English with equivalent warning code IN OWNERS MANUAL and printed in the form of sticker and displayed in appropriate location visible to driver.

Table 1

S. No	Category	Warning Stage	Warning Code	Text message
1	DEF/ Urea/Reagent Level Monitoring	Stage - 1	E 01	DEF LEVEL LOW
2		Stage - 2	E 02	DEF LEVEL VERY LOW NO START ALLOWED AFTER ---- KM
3		Stage - 3	E 03	RESTART DENIED AFTER ENGINE OFF, FILL DEF
4		Stage - 4	E 04	START DENIED, FILL DEF
5	DEF/Urea/ Reagent Quality Monitoring	Stage - 1	E 05	DEF QUALITY POOR
6		Stage - 2	E 06	DEF QUALITY VERY POOR, NO START ALLOWED AFTER ---- KM
7		Stage - 3	E 07	RESTART DENIED AFTER ENGINE OFF, CHECK DEF

				QUALITY
8		Stage - 4	E 08	START DENIED, CHECK DEF QUALITY
9	SCR system / NOx reduction system monitoring	Stage - 1	E 09	DEF SYSTEM MALFUNCTIONING , VISIT SERVICE CENTER
10		Stage - 2	E 10	DEF SYSTEM ERROR. NO START ALLOWED AFTER ----KM
11		Stage - 3	E 11	RESTART DENIED AFTER ENGNE OFF, DEF MALFUNCTION
12		Stage - 4	E 12	START DENIED , DEF MALFUNCTION
----KM = Average driving range of the vehicle with a complete tank of fuel				
*Note:				
a) Alternate proposal shall be applicable only for vehicles having a power to kerb weight ratio PMR ≤ 22 W/kg and max design speed ≤ 70 kmph.				
b) Alternate proposal will be valid only up to 31st March 2023				

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THE AUTOMOTIVE RESEARCH ASSOCIATION OF INDIA

P. B. NO. 832, PUNE 411 004

ON BEHALF OF

AUTOMOTIVE INDUSTRY STANDARDS COMMITTEE

UNDER

CENTRAL MOTOR VEHICLES RULES - TECHNICAL STANDING COMMITTEE

SET-UP BY

MINISTRY OF ROAD TRANSPORT & HIGHWAYS

(DEPARTMENT OF ROAD TRANSPORT & HIGHWAYS)

GOVERNMENT OF INDIA

17th January 2020

AUTOMOTIVE INDUSTRY STANDARD

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

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April 2019

Status chart of the Standard to be used by the purchaser for updating the record

Sr. No.	Corrigenda	Amendment	Revision	Date	Remark	Misc.
General Remarks:						

INTRODUCTION

In India, the mass emission norms based on Indian Driving Cycle (IDC) were notified under CMVR in 1989. The first mass emission norms for vehicles were enforced from 1st April 1991 for Gasoline vehicles and from 1st April 1992 for Diesel vehicles. Since then, progressively emission norms have been tightened.

Government of India has notified migration to Bharat Stage VI (BS VI) emissions norms for 2, 3 and 4 wheeled vehicles from 1st April 2020. For Agricultural Tractors, Construction Equipment Vehicles and Combine Harvesters (vehicles having power exceeding 37 kW) next stage emission norms Bharat Stage (CEV/TREM) – IV) are notified from 1st October 2020 and Bharat Stage (CEV/TREM) – V) from 1st April 2024. Test procedure for Type Approval and CoP for above emission norms shall be as per various parts of AIS-137, as applicable.

This Part 3 of AIS-137 prescribes Test Method, Testing Equipment and related procedures for Type Approval and Conformity of Production (COP) Testing of Vehicles of Category M and N having GVW not exceeding 3,500 kg for BS VI emission norms as per CMV Rules 115, 116 and 126.

Chapter 20 on Verifying Real Driving Emissions (RDE) will be included after finalized recommendations of the Indian Real Driving Emissions (IRDE) Committee are adopted.

While preparing this standard, considerable assistance has been taken from following regulations/documents:

i)	UN R 83 (Supplement 3 to the 07 series of amendments – Date of entry into force: 9 February 2017): Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements.
ii)	Regulation (EC) No 715/2007 of The European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information
iii)	Commission Regulation (EC) No. 692/2008 of July 18, 2008 implementing and amending Regulation (EC) No. 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information. (Including Corrigendum) *As amended by Commission Regulations (EU) 566/2011, 459/2012, 630/2012, 143/2013, 195/2013, 136/2014, 2015/45, 2016/427, (EU) 2016/646, (EU) 2017/1151 and (EU) No. 2017/1221

iv)	Commission Regulation (EU) 2017/1154 of 7 June 2017 amending Regulation (EU) 2017/1151 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Regulation (EC) No 692/2008 and Directive 2007/46/EC of the European Parliament and of the Council as regards real-driving emissions from light passenger and commercial vehicles (Euro 6)
v)	UN Regulation 101 (Supplement 6 to the 01 series of amendments. Date of entry into force 18.06.2016) : Uniform provisions concerning the approval of passenger cars powered by an internal combustion engine only, or powered by a hybrid electric power train with regard to the measurement of the emission of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range, and of categories M1 and N1 vehicles powered by an electric power train only with regard to the measurement of electric energy consumption and electric range
vi)	Doc. No.: MoRTH/CMVR/ TAP-115/116: Issue No.:4: Document on test method, testing equipment and related procedures for testing type approval and conformity of production (CoP) of vehicles for emission as per CMV Rules 115, 116 and 126.
vii)	Government of India, Gazette Notification G.S.R. 889 (E) dated 16th September, 2016 regarding implementation of Bharat Stage VI (BS VI) emission norms for 2, 3 and 4 wheeled vehicles.

The Committee Composition for formulation of this standard is given in Annexure 1.

After approval of the standard by SCOE, The Automotive Research Association of India, (ARAI), Pune, being the Secretariat of the AIS Committee, has published this standard. For better dissemination of this information ARAI may publish this standard on their web site.

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CHAPTER 1

OVERALL REQUIREMENTS

1.0 SCOPE

This part applies to the emission of vehicles equipped with positive-ignition engines including hybrids and compression - ignition engines including hybrids for all M and N category vehicles with GVW up to 3,500 kg for Bharat Stage VI.

In addition, this Part lays down rules for in-service conformity, durability of pollution control devices, On-Board Diagnostic (OBD) systems, Real Driving Emission (RDE) and measurement of fuel consumption.

1.1 This Part shall apply to vehicles of categories M1, M2, N1 and N2 with a reference mass not exceeding 2,610 kg. At the manufacturer's request, type approval granted under this Part may be extended from vehicles mentioned above to M1, M2, N1 and N2 vehicles with a reference mass not exceeding 2,840 kg and which meet the conditions laid down in this Part.

1.2 If a vehicle is tested for type approval on chassis dynamometer having reference mass up to 2,610 kg, manufacturer may seek type approval extensions up to reference mass of 2,840 kg for its variants, even if intended variant GVW exceeds beyond 3,500 kg.

This Part should be read in conjunction with applicable Gazette Notification for which the vehicle is subjected to test.

2.0 DEFINITIONS

For the purposes of this Part the following definitions shall apply:

2.1 **"Reference mass"** means the "unladen mass" of the vehicle increased by a uniform figure of 150kg

2.2 **"Unladen mass"** means the mass of the vehicle in running order without the uniform mass of the driver of 75kg, passengers or load, but with the fuel tank 90 % full and the usual set of tools and spare wheel on board, where applicable;

2.3 **"Gross Vehicle Weight (GVW)"** means the technically permissible maximum weight declared by the vehicle manufacturer.

2.4 **"Gaseous pollutants"** means the exhaust gas emissions of carbon monoxide, oxides of nitrogen expressed in nitrogen dioxide (NO2) equivalent and hydrocarbons assuming ratio of:

(a) C1H2.525 for Liquefied Petroleum Gas (LPG)

(b) C1H4 for Natural Gas (NG) and biomethane

(c) C1H1.89O0.016 for gasoline (E5)

(d) C1H1.93O0.033 for gasoline (E10)

(e) $C_1H_{1.86}O_{0.005}$ for diesel (B5)

(f) $C_1H_{1.86}O_{0.007}$ for diesel (B7)

(g) $C_1H_{2.74}O_{0.385}$ for ethanol (E85)

(h) C_2H_5OH for ethanol (E100)

2.5 **"Particulate pollutants"** means components of the exhaust gas which are removed from the diluted exhaust gas at a maximum temperature of 325 K (52°C) by means of the filters described in Appendix 1 of Chapter 8 of this Part.

2.5.1 **"Particulate numbers"** means the total number of particles of a diameter greater than 23nm diameter present in the diluted exhaust gas after it has been conditioned to remove volatile material, as described in Appendix 2 of Chapter 8 of this Part.

2.6 **"Exhaust emissions"** means:

(a) For Positive-Ignition (P.I.) engines, emissions of gaseous, particulate pollutants and particulate numbers (For Gasoline Direct Injection engines only)

(b) For Compression-Ignition (C.I.) engines, emissions of gaseous pollutants, particulate pollutants and particulate numbers.

2.7 **"Evaporative emissions"** means the hydrocarbon vapours lost from the fuel system of a motor vehicle other than those from exhaust emissions;

2.7.1 **"Tank breathing losses"** are hydrocarbon emissions caused by temperature changes in the fuel tank (assuming a ratio of $C_1H_{2.33}$).

2.7.2 **"Hot soak losses"** are hydrocarbon emissions arising from the fuel system of a stationary vehicle after a period of driving (assuming a ratio of $C_1 H_{2.20}$).

2.8 **"Engine crankcase"** means the spaces in or external to an engine which are connected to the oil sump by internal or external ducts through which gases and vapour can escape.

2.9 **"Cold start device"** means a device that temporarily enriches the air/fuel mixture of the engine thus assisting the engine to start.

2.10 **"Starting aid"** means a device which assists engine start up without enrichment of the air/ fuel mixture of the engine, e.g. glow plug, injection timing change, etc.

2.11 **"Engine capacity"** means:

2.11.1 For reciprocating piston engines, the nominal engine swept volume;

2.11.2 For rotary piston engines (Wankel), twice the nominal swept volume of a combustion chamber per piston;

2.12 **"Pollution control devices"** means those components of a vehicle that control and/or limit exhaust and evaporative emissions.

2.13 **"On-Board Diagnostic (OBD)"** means an on-board diagnostic system for emission control, which has the capability of identifying the likely area of malfunction by means of fault codes stored in computer memory.

2.14 **"In-service test"** means the test and evaluation of conformity conducted in accordance with Chapter 18 of this Part.

2.15 **"Properly maintained and used"** means, for the purpose of a test vehicle, that such a vehicle satisfies the criteria for acceptance of a selected vehicle laid down in clause 2 of Appendix 1 of Chapter 18 of this Part.

2.16 **"Defeat device"** means any element of design which senses temperature, vehicle speed, engine rotational speed, transmission gear, manifold vacuum or any other parameter for the purpose of activating, modulating, delaying or deactivating the operation of any part of the emission control system, that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use. Such an element of design may not be considered a defeat device if:

2.16.1 The need for the device is justified in terms of protecting the engine against damage or accident and for safe operation of the vehicle; or

2.16.2 The device does not function beyond the requirements of engine starting; or

2.16.3 Conditions are substantially included in the test procedures for verifying evaporative emissions and tailpipe emissions.

2.17 **"Family of vehicles"** means a group of vehicle types identified by a parent vehicle for the purpose of Chapter 13 of this Part.

2.18 **"Bio-fuel"** means liquid or gaseous fuel for transport, produced from biomass.

2.19 **"Approval of a vehicle"** means the approval of a vehicle type with regard to the limitation of the following conditions:

2.19.1 Limitation of tailpipe emissions by the vehicle, evaporative emissions, crankcase emissions, durability of pollution control devices, Real Driving Emission (RDE), measurement of fuel consumption, engine power and on-board diagnostics of vehicles fueled with unleaded gasoline, or which can be fuelled with either unleaded gasoline and LPG or NG/biomethane or Hydrogen or biofuels and Ethanol E85 or E100.

2.19.2 Limitation of tailpipe emissions, durability of pollution control devices, Real Driving Emission (RDE), measurement of fuel consumption, engine power and on-board diagnostics of vehicles fueled with diesel fuel or which can be fuelled with either diesel fuel and biofuel or biofuel or dual fuel.

2.19.3 Limitation of tailpipe emissions, crankcase emissions, durability of pollution control devices, Real Driving Emission (RDE), measurement of fuel consumption, engine power and on-board diagnostics of vehicles fuelled with LPG or NG/biomethane ;

2.20 **"Periodically regenerating system"** means an anti-pollution device (e.g. catalytic converter, particulate trap) that requires a periodical regeneration process in less than 4,000 km of normal vehicle operation. During cycles where regeneration occurs, emission standards can be exceeded. If a regeneration of an anti-pollution device occurs at least once per Type I test and that has already regenerated at least once during vehicle preparation cycle, it will be considered as a continuously regenerating system which does not require a special test procedure. Chapter 15 of this Part does not apply to continuously regenerating systems.

At the request of the manufacturer, the test procedure specific to periodically regenerating systems will not apply to a regenerative device if the manufacturer provides data to the Test Agency that, during cycles where regeneration occurs, emissions remain below the standards given in applicable notification.

2.21 Hybrid Vehicles (HV)

2.21.1 General definition of Hybrid Vehicles (HV):

"Hybrid vehicle (HV)" means a vehicle with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion.

2.21.2 Definition of Hybrid Electric Vehicles (HEV):

"**Hybrid electric vehicle (HEV)"** means a vehicle that, including vehicles which draw energy from a consumable fuel only for the purpose of recharging the electrical energy/power storage device that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power:

a) A consumable fuel;
b) A battery, capacitor, flywheel/generator or other electrical energy/ power storage device

2.22 **"Mono-fuel vehicle"** means a vehicle that is designed to run primarily on one type of fuel;

2.22.1 **"Mono-fuel gas vehicle"** means a vehicle that is designed primarily for permanent running on LPG or NG/biomethane or hydrogen, but may also have a gasoline system for emergency purposes or starting only, where the gasoline tank does not contain more than 5 litres of gasoline.

2.23 **"Bi-fuel vehicle"** means a vehicle with two separate fuel storage systems that is designed to run on only one fuel at a time. The simultaneous use of both fuels is limited in amount and duration.

2.23.1 **"Bi-fuel gas vehicle"** means a bi fuel vehicle that can run on gasoline and also on either LPG, NG/biomethane or hydrogen (gas mode).

2.24 **"Alternative fuel vehicle"** means a vehicle designed to be capable of running on at least one type of fuel that is either gaseous at atmospheric temperature and pressure, or substantially non-mineral oil derived.

2.25 **"Flex fuel vehicle"** means a vehicle with one fuel storage system that can run on different mixtures of two or more fuels.

2.25.1 **"Flex fuel ethanol vehicle"** means a flex fuel vehicle that can run on gasoline or a mixture of gasoline and ethanol up to 85 or 100 per cent ethanol blend (E85 or E100).

2.25.2 **"Flex fuel biodiesel vehicle"** means a flex fuel vehicle that can run on mineral diesel or a mixture of mineral diesel and biodiesel.

2.26 In the context of In Use Performance Ratio Monitoring ($IUPR_M$), **"cold start"** means an engine coolant temperature (or equivalent temperature) at engine start of less than or equal to 35 °C and less than or equal to 7 K higher than ambient temperature (if available) at engine start.

2.27 **"Direct injection engine"** means an engine which can operate in a mode where the fuel is injected into the intake air after the air has been drawn through the inlet valves.

2.28 **"Electric power train"** means a system consisting of one or more electric energy storage devices, one or more electric power conditioning devices and one or more electric machines that convert stored electric energy to mechanical energy delivered at the wheels for propulsion of the vehicle.

2.29 **"Pure electric vehicle"** means a vehicle powered by an electric power train only.

2.30 **"Hydrogen fuel cell vehicle"** means a vehicle powered by a fuel cell that converts chemical energy from hydrogen into electric energy, for propulsion of the vehicle.

2.31 **"Net power"** means the power obtained on a test bench at the end of the crankshaft or its equivalent at the corresponding engine or motor speed with the auxiliaries tested in accordance with AIS-137 (Part 5) and determined under reference atmospheric conditions.

2.32 **"Maximum net power"** means the maximum value of the net power measured at full engine load.

2.33 **"Maximum 30 minutes power"** means the maximum net power of an electric drive train at Direct Current (DC) voltage as set out in AIS-137 (Part 5).

2.34 **"Cold start"** means an engine coolant temperature (or equivalent temperature) at engine start less than or equal to 35 °C and less than or equal to 7 K higher than ambient temperature (if available) at engine start.

3.0 APPLICATION FOR APPROVAL

3.1 The application for approval of a vehicle type with regard to tail pipe emissions, crankcase emissions, evaporative emissions, Real Driving Emission (RDE), measurement of fuel consumption, engine power and durability of pollution control devices, as well as to its on-board diagnostic (OBD) system shall be submitted by the vehicle manufacturer to Test Agency.

3.1.1 In addition, the manufacturer shall submit the following information:

(a) In the case of vehicles equipped with positive-ignition engines, a declaration by the manufacturer of the minimum percentage of misfires out of a total number of firing events that would either result in emissions exceeding the limits given in applicable Gazette Notification, if that percentage of misfire had been present from the start of a Type I test as described in Chapter 3 of this Part, or that could lead to an exhaust catalyst, or catalysts, overheating prior to causing irreversible damage;

(b) Detailed written information fully describing the functional operation characteristics of the OBD system, including a listing of all relevant parts of the emission control system of the vehicle that are monitored by the OBD system;

(c) A description of the malfunction indicator used by the OBD system to signal the presence of a fault to a driver of the vehicle;

(d) A declaration by the manufacturer that the OBD system complies with the provisions of clause 7 of Appendix1 of Chapter 14 of this Part relating to in-use performance under all reasonably foreseeable driving conditions;

(e) A plan describing the detailed technical criteria and justification for incrementing the numerator and denominator of each monitor that shall fulfil the requirements of clause 7.2 and 7.3 of Appendix 1 of Chapter 14 of this Part, as well as for disabling numerators, denominators and the general denominator under the conditions outlined in clause 7.7 of Appendix 1 of Chapter 14 of this Part;

(f) A description of the provisions taken to prevent tampering with and modification of the emission control computer;

(g) If applicable, the particulars of the vehicle family as referred to in Appendix 2 of Chapter 14 of this Part;

(h) Where appropriate, copies of other type approvals with the relevant data to enable extension of approvals and establishment of deterioration factors.

3.1.2 For the tests described in clause 3 of Chapter 14 of this Part, a vehicle representative of the vehicle type or vehicle family fitted with the OBD system to be approved shall be submitted to the Test Agency responsible for the type approval test. If the Test Agency determines that the submitted vehicle does not fully represent the vehicle type or vehicle family described in Appendix 2 of Chapter 14 of this Part, an alternative and if necessary an additional vehicle shall be submitted for test in accordance with clause 3 of Chapter 14 to this Part.

3.2 A model of the information document relating to exhaust emissions, evaporative emissions, durability, Real Driving Emission (RDE), measurement of fuel consumption, engine power and the On-Board Diagnostic (OBD) system is given in AIS-007,as amended from time to time.

3.2.1 Where appropriate, copies of other type approvals with the relevant data to enable extensions of approvals and establishment of deterioration factors shall be submitted.

3.3 For the tests described in clause 5 of this Chapter a vehicle representative of the vehicle type to be approved shall be submitted to the Test Agency responsible for the approval tests.

3.3.1 The application referred to in clause 3.1. of this Chapter shall be drawn up in accordance with the model of the information document set out as per AIS-007, as amended from time to time.

3.3.2 For the purposes of clause 3.1.1(d) of this Chapter, the manufacturer shall use the model of a manufacturer's certificate of compliance with the OBD in-use performance requirements set out in Appendix 1 to this Chapter.

3.3.3 For the purposes of clause 3.1.1. (e) of this Chapter, the Test Agency that grants the approval shall make the information referred to in that point available to the test agency upon request.

3.3.4 For the purposes of sub clauses (d) and (e) of clause 3.1.1. of this Chapter, Test Agency shall not approve a vehicle if the information submitted by the manufacturer is inappropriate for fulfilling the requirements of clause 7. of Appendix 1 of Chapter 14 of this Part. Clauses 7.2., 7.3. and 7.7. of Appendix 1 of Chapter 14 of this Part shall apply under all reasonably foreseeable driving conditions.

For the assessment of the implementation of the requirements set out in the first and second sub clauses, the test agency shall take into account the state of technology

3.3.5 For the purposes of clause 3.1.1 (f) of this Chapter, the provisions taken to prevent tampering with and modification of the emission control computer shall include the facility for updating using a manufacturer-approved programme or calibration.

3.3.6 For the tests specified in Table 1 of this Chapter, the manufacturer shall submit to the Test Agency responsible for the type approval tests a vehicle representative of the type to be approved.

3.3.7 The application for type approval of flex-fuel vehicles shall comply with the additional requirements laid down in clauses 4.1 and 4.2 of this Chapter.

3.3.8 Changes to the make of a system, component or separate technical unit that occur after a type approval shall not automatically invalidate a type approval, unless its original characteristics or technical parameters are changed in such a way that the functionality of the engine or pollution control system is affected.

3.3.9 The manufacturer shall equip vehicles so that the components likely to affect emissions are designed, constructed and assembled so as to enable the vehicle, in normal use, to comply with this Part and its implementing measures

4.0 ADDITIONAL REQUIREMENTS FOR APPROVAL OF FLEX FUEL VEHICLES

4.1 For the type approval of a flex fuel ethanol or biodiesel vehicle, the vehicle manufacturer shall describe the capability of the vehicle to adapt to any mixture of gasoline and ethanol fuel (up to an 85% or 100 % ethanol blend) or diesel and biodiesel that may occur across the market.

4.2 For flex fuel vehicles, the transition from one reference fuel to another between the tests shall take place without manual adjustment of the engine settings.

4.3 Requirements for approval regarding the OBD system

4.3.1 The manufacturer shall ensure that all vehicles are equipped with an OBD system.

4.3.2 The OBD system shall be designed, constructed and installed on a vehicle so as to enable it to identify types of deterioration or malfunction over the entire life of the vehicle.

4.3.3 The OBD system shall comply with the requirements of this Part during conditions of normal use.

4.3.4 When tested with a defective component, in accordance with Appendix 1 of Chapter 14 of this Part, the OBD system malfunction indicator shall be activated. The OBD system malfunction indicator may also activate during this test at levels of emissions below the OBD threshold limits specified in applicable Gazette notification.

4.3.5 The manufacturer shall ensure that the OBD system complies with the requirements for in-use performance set out in clause7 of Appendix 1 of Chapter 14 of this Part under all reasonably foreseeable driving conditions.

4.3.6 In-use performance related data to be stored and reported by a vehicle's OBD system according to the provisions of clause 7.6 of Appendix 1 of Chapter 14 of this Part shall be made readily available by the manufacturer to national authorities and independent operators without any encryption.

4.4 Additional requirements for vehicles fuelled by LPG or NG/Biomethane.

4.4.1 The additional requirements for vehicles fuelled by LPG or NG/Biomethane are provided in Chapter 13 of this Part.

5.0 SPECIFICATIONS AND TESTS

5.1 General

5.1.1 The components liable to affect the emission of pollutants shall be so designed, constructed and assembled as to enable the vehicle, in normal use, despite the vibration to which they may be subjected, to comply with the provisions of this Part.

5.1.2 The use of a defeat device is prohibited.

5.1.3 Provisions for electronic system security

5.1.3.1 Any vehicle with an emission control computer shall include features to prevent modification, except as authorized by the manufacturer. The manufacturer shall authorize modifications if these modifications are necessary for the diagnosis, servicing, inspection, retrofitting or repair of the vehicle. Any reprogrammable computer codes or operating parameter shall be resistant to tampering and afford a level of protection at least as good as the provisions in ISO DIS 15031-7, dated 15 March 2001 (SAE J2186 dated October 1996). Any removable calibration memory chips shall be potted, encased in a sealed container or protected by electronic algorithms and shall not be changeable without the use of specialized tools and procedures. Only features directly associated with emissions calibration or prevention of vehicle theft may be so protected.

5.1.3.2 Computer-coded engine operating parameters shall not be changeable without the use of specialized tools and procedures (e.g. soldered or potted computer components or sealed (or soldered) computer enclosures).

5.1.3.3 In the case of mechanical fuel-injection pumps fitted to compression-ignition engines, manufacturers shall take adequate steps to protect the maximum fuel delivery setting from tampering while a vehicle is in service.

5.1.3.4 Manufacturers may apply to the Test Agency for an exemption to one of these requirements for those vehicles which are unlikely to require protection. The criteria that the Test Agency will evaluate in considering an exemption will include, but are not limited to, the current availability of performance chips, the high-performance capability of the vehicle and the projected sales volume of the vehicle.

5.1.3.5 Manufacturers using programmable computer code systems (e.g. Electrical Erasable Programmable Read-Only Memory, EEPROM) shall deter unauthorized reprogramming. Manufacturers shall include enhanced tamper protection strategies and write protect features requiring electronic access to an off-site computer maintained by the manufacturer. Methods giving an adequate level of tamper protection will be approved by the Test Agency.

5.2 Test procedure

Table 1 of this Chapter illustrates the various possibilities for type-approval of a vehicle.

5.2.1 Positive ignition engine-powered vehicles and hybrid electric vehicles equipped with a positive-ignition engine shall be subject to the following tests:

Type I (verifying the average exhaust emissions after a cold start)
Type II (carbon monoxide emission at idling speed)
Type III (emission of crankcase gases)
Type IV (evaporation emissions)
Type V (durability of anti-pollution devices)
OBD-test
Engine power test

5.2.2 Positive ignition engine-powered vehicle and hybrid electric vehicles equipped with positive-ignition engine fuelled with LPG or NG/biomethane (mono or bi-fuel) shall be subjected to the following tests: (According to Table 1)

Type I (verifying the average exhaust emissions after a cold start)
Type II (carbon monoxide emissions at idling speed);
Type III (emission of crankcase gases);
Type IV (evaporative emissions), where applicable;
Type V (durability of anti-pollution devices);
OBD test
Engine power test

5.2.3 Compression ignition engine-powered vehicles and hybrid electric vehicles equipped with a compression ignition engine shall be subject to the following tests: (According to Table 1)

- Type I (verifying the average exhaust emissions after a cold start);
- Type V (durability of anti-pollution control devices)
- Emission of visible pollutants over the full load curve and free acceleration smoke test
- OBD test
- Engine power test

Table 1
Application of Test Requirements for Type-Approval – BS VI

	Vehicles with Positive Ignition Engines including Hybrids									Vehicles with Compression Ignition Engines including Hybrids		
	Mono Fuel					Bi- Fuel[1]			Flex Fuel[1]	Flex Fuel	Mono Fuel	Dual Fuel
Reference Fuel	Gasoline (E5)	LP G	CNG/ Bio-Methane/ Bio-Gas/ LNG	Hydrogen (ICE) 3	HCNG (Hydrogen + CNG)	Gasoline (E5) / LPG	Gasoline (E5) / CNG / Bio- Methane	Gasoline (E5) / Hydrogen (ICE)3	Gasoline (E5) / Ethanol (E85)/(E100)	Diesel (B7) / Bio-diesel up to 100%[5]	Dies el (B7)	Dies el + CNG
Gaseous Pollutants (Type 1 Test)	Yes	Ye s	Yes	Yes[2]	Yes	Yes (Both Fuels)	Yes (Both Fuels)	Yes (Both Fuels) [2]	Yes (Both Fuels)	Yes	Yes	Yes
Particulate Mass and Particulate Number (Type1 Test)	Yes [4]	-	-	-	-	Yes (Gasoline only)	Yes (Gasoline only)	Yes (Gasoline Only)	Yes (Both Fuels)	Yes	Yes	Yes
Idle Emissions (Type II Test)	Yes	Ye s	Yes	-	Yes	Yes (Both Fuels)	Yes (Both Fuels)	Yes (Gasoline Only)	Yes (Both Fuels)	-	-	-
Crankcase Emissions (Type III Test)	Yes	Ye s	Yes	- -	Yes	Yes (Gasoline only)	Yes (Gasoline only)	Yes (Gasoline only)	Yes (Gasoline only)	-	-	-
Evaporative Emissions (Type IV test)	Yes	-	-	-	-	Yes (Gasoline only)	Yes (Gasoline only)	Yes (Gasoline Only)	Yes (Gasoline only)	-	-	-
Durability (Type V Test)	Yes	Ye s	Yes	Yes	Yes	Yes (Gasoline only)	Yes (Gasoline only)	Yes (Gasoline Only)	Yes (Gasoline only)	Yes (B7 only)	Yes	Yes

In- Service Conformity	Yes	Ye s	Yes	Yes	Yes	Yes (Both fuels)	Yes (Both fuels)	Yes (Gasoline only)	Yes (Both fuels)	Yes (B7 only)	Yes	Yes
On-Board Diagnostics and IUPR$_M$	Yes	Ye s	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
(6)CO_2 emission and fuel consumption	Yes	Ye s	Yes	Yes	Yes	Yes (Both fuels)	Yes (Both fuels)	Yes (Both fuels)	Yes (Both fuels)	Yes (Both fuels)	Yes	Yes
Smoke Opacity	--	--	--	--	--	--	--	--	--	Yes	Yes	--
Engine Power	Yes	Ye s	Yes	Yes	Yes	Yes (Both fuels)	Yes (Both fuels)	Yes (Both fuels)	Yes (Both fuels)	Yes	Yes	Yes

(1) When a bi-fuel vehicle has flex fuel option, both test requirements are applicable. Vehicle tested with E100 need not to be tested for E85.

(2) Only NOx emissions shall be determined when the vehicle is running on Hydrogen.

(3) Reference Fuel is ‘Hydrogen for Internal Combustion Engine as specified in Annexure IV-W. of CMVR 115/116.

(4) For Positive ignition, particulate mass and number limits for vehicles with positive ignition engines including hybrids shall apply only to vehicles with direct injection engines.

(5) Vehicle fuelled with Bio diesel blends up to 7% will be tested with reference diesel (B7) and vehicles fueled with Bio diesel blends above 7% will be tested with respective blends.

(6) CO_2 emission and fuel consumption shall be measured as per procedure laid down in AIS-137, as amended from time to time.

5.3. **Description of Tests**

5.3.1. Type I test (Simulating the average exhaust emissions after a cold start).

5.3.1.1 Figure 1 of this Chapter illustrates the routes for Type I test. This test shall be carried out on all vehicles referred to in clause 1 of this part.

5.3.1.2 The vehicle is placed on a chassis dynamometer equipped with a means of load and inertia simulation.

5.3.1.2.1 A test lasting a total of 19 minutes and 40 seconds, made up of two parts, One and Two is performed without interruption. An un-sampled period of not more than 20 seconds may, with the agreement of the manufacturer, be introduced between the end of Part One and the beginning of Part Two in order to facilitate adjustment of the test equipment.

5.3.1.2.2 Vehicles that are fuelled with either gasoline or a gaseous fuel, but where the gasoline system is fitted for emergency purposes or starting only and which the gasoline tank cannot contain more than 5 litres of gasoline will be regarded for the Type I test as vehicles that can only run on a gaseous fuel.

5.3.1.2.3 Part One of the test is made up of four elementary urban cycles. Each elementary urban cycle comprises fifteen phases (idling, acceleration, steady speed, deceleration, etc.).

5.3.1.2.4 Part Two of the test is made up of one extra-urban cycle. The extra-urban cycle comprises 13 phases (idling, acceleration, steady speed, deceleration, etc.).

5.3.1.2.5 During the test, the exhaust gases are diluted and a proportional sample collected in one or more bags. The exhaust gases of the vehicle tested are diluted, sampled and analyzed, following the procedure described below, and the total volume of the diluted exhaust is measured. Not only the carbon monoxide, hydrocarbon and nitrogen oxide emissions but also the particulate pollutant emissions from vehicles equipped with compression-ignition engines and Gasoline GDI engines are recorded.

5.3.1.3 The test is carried out using the procedure of Type I test as described in Chapter 3 of this Part. The method used to collect and analyze the gases shall be as prescribed in Appendix 2 of Chapter 4 and Chapter 7 of this Part, and the method to sample and analyse the particulates shall be as prescribed in Appendix 1 and Appendix 2 of Chapter 8 of this Part.

5.3.1.4 Subject to the requirements of clause 5.3.1.5 of this Chapter, the test shall be repeated three times. The results are multiplied by the appropriate deterioration factors obtained from clause 5.3.5.2 and in the case of periodically regenerating systems as defined in clause 2.20, multiplicative or additive Ki factor must be applied obtained from Chapter 15 of this Part. The resulting masses of gaseous emissions and in the case of vehicles equipped with compression-ignition engines, the mass of particulates obtained in each test shall be less than the limits as indicated in Gazette notification.

5.3.1.4.1 Notwithstanding the requirements of clause 5.3.1.4 of this Chapter, for each pollutant or combination of pollutants, one of the three resulting masses obtained may exceed, by not more than 10% the limit prescribed, provided the arithmetical mean of the three results is below the prescribed limit. Where the prescribed limits are exceeded for more than one pollutant, it is immaterial whether this occurs in the same test or in different tests.

5.3.1.4.2 When the tests are performed with gaseous fuels, the resulting mass of gaseous emissions shall be less than the limits for gasoline-engined vehicles as prescribed in Gazette notification.

5.3.1.5 The number of tests prescribed in clause 5. 3. 1. 4 of this Chapter is reduced in the conditions hereinafter defined, where V_1 is the result of the first test and V_2 the result of the second test for each pollutant or for the combined emission of two pollutants subject to limitation.

5.3.1.5.1 Only one test is performed if the result obtained for each pollutant or for the combined emission of two pollutants subject to limitation, is less than or equal to 0.70 L (i.e. $V_1 \leq 0.70$ L).

5.3.1.5.2 If the above requirement of clause 5.3.1.5.1 of this Chapter is not satisfied, only two tests are performed if, for each pollutant or for the combined emission of two pollutants subject to limitation, the following requirements are met:

$V_1 \leq 0.85$ L and $V_1 + V_2 < 1.70$ L and $V_2 \leq$ L. Figure 1 below depicts the scheme

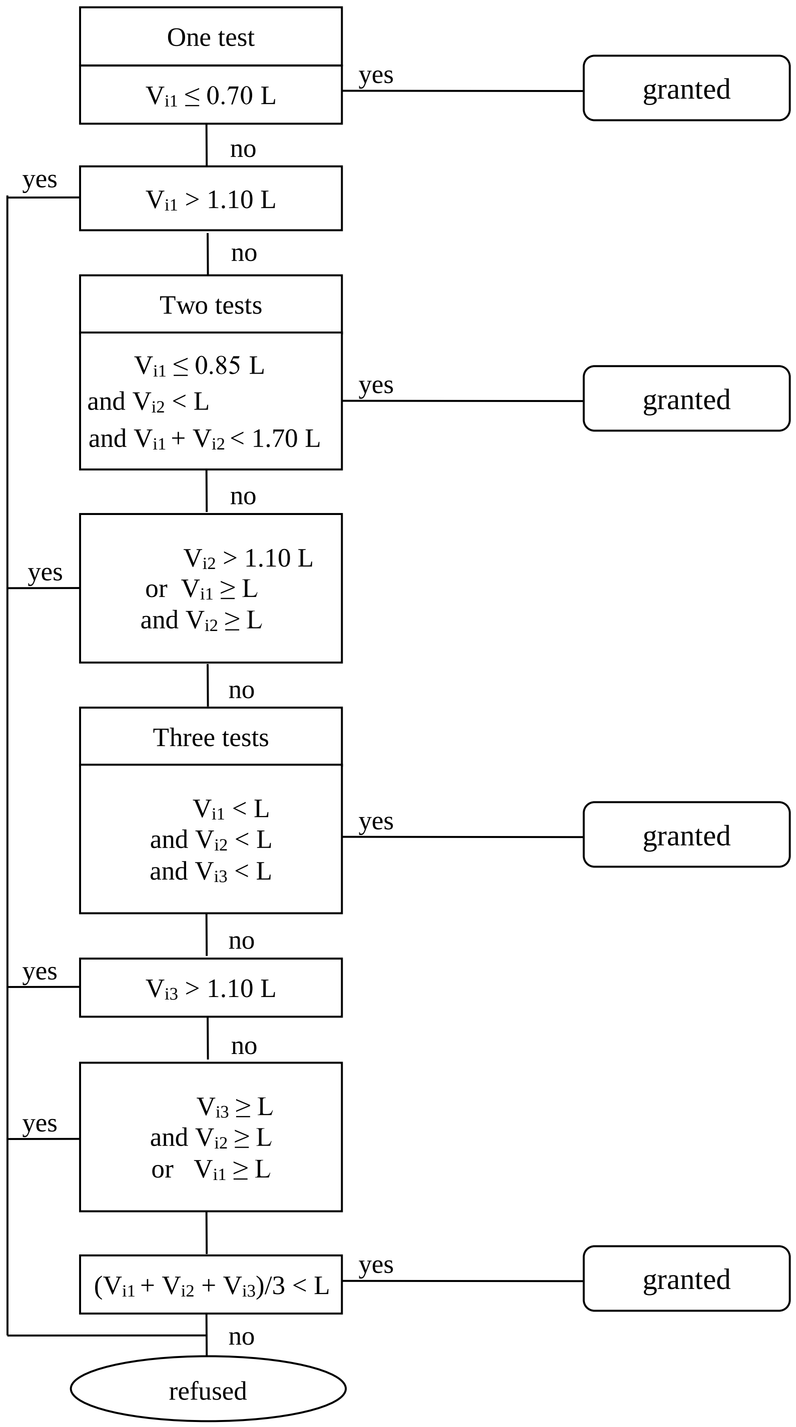


Figure 1

Flow Chart for Type I Type -Approval

5.3.2 Type II Test (Emission Test at Idling Speed)

5.3.2.1 This test is carried out on all vehicles powered by positive-ignition engines having:

5.3.2.1.1 Vehicles that can be fueled either with gasoline or with LPG or NG/biomethane shall be tested in the test Type II on both fuels.

5.3.2.1.2 Notwithstanding the requirement of clause 5.3.2.1.1 of this Chapter, Vehicles that can be fueled with either gasoline or a gaseous fuel, but where the gasoline system is fitted for emergency purposes or starting only and which the gasoline tank cannot contain more than 5 litres of gasoline will be regarded for the test Type II as vehicles that can only run on a gaseous fuel.

5.3.2.2 For the Type II test set out in Chapter 9 of this Part, at normal engine idling speed, the maximum permissible carbon monoxide content in the exhaust gases shall be that stated by the vehicle manufacturer. However the maximum content of gaseous pollutant shall not exceed the notified limits.

At high idle speed, the carbon monoxide content by volume of the exhaust gases shall not exceed notified value, with the engine speed being at least 2,000 min^{-1} and Lambda being as per CMVR 116 or in accordance with the specifications of the manufacturer.

5.3.3 Type III test (Verifying Emissions of Crankcase Gases)

5.3.3.1 This test shall be carried out on all vehicles referred in clause 1 of this Chapter except those having compression-ignition engines.

5.3.3.1.1 Vehicles that can be fueled either with gasoline or with LPG or NG should be tested in the Type III test on gasoline only.

5.3.3.1.2 Notwithstanding the requirement of clause 5.3.3.1.1 of this Chapter, vehicles that can be fueled with either gasoline or a gaseous fuel, but where the gasoline system is fitted for emergency purposes or starting only and which the gasoline tank cannot contain more than 5 liters of gasoline will be regarded for the test Type III as vehicles that can only run on a gaseous fuel.

5.3.3.2 The engine's crankcase ventilation system shall not permit the emission of any of the crankcase gases into the atmosphere, when tested in accordance with Chapter 10 of this Part.

5.3.4 Type IV test (Determination of Evaporative Emissions)

5.3.4.1 This test shall be carried out on all vehicles referred in clause 1 of this Chapter except those vehicles having a compression-ignition engine, vehicles fueled with LPG or NG/biomethane.

5.3.4.1.1 Vehicles that can be fueled either with gasoline or with LPG or with NG/biomethane should be tested in the Type IV test on gasoline only.

5.3.4.2 When tested in accordance with Chapter 11 of this Part, evaporative emissions shall be less than prescribed limit in Gazette notification

5.3.5 Type V test (Durability of pollution control devices)

5.3.5.1 This test shall be carried out on all vehicles prescribed in clause 1 of this Chapter for which the test specified in clause 5.3.1 of this Chapter applies. The test represents an ageing test of 160,000 km driven as per Chapter 12 of this Part on a test track, on the road or on a chassis dynamometer. Alternatively, bench ageing durability test, for evaluating the Deterioration factor may be carried out as described in Chapter 12 of this Part.

5.3.5.1.1 Vehicles that can be fueled either with gasoline or with LPG or NG should be tested in the Type V test on gasoline only. In that case the deterioration factor found with unleaded gasoline will also be taken for LPG or NG.

5.3.5.2 Notwithstanding the requirement of clause 5.3.5.1. of this Chapter, a manufacturer may choose to have the deterioration factors from the following Table 2 of this Chapter used as an alternative to testing to clause 5.3.5.1. of this Chapter.

Table 2
Assigned Deterioration Factors

Engine Category	CO	THC	NMHC	NO_x	HC+NO_x	Particulate Matter (PM)	Number of particles (PN)
Positive-ignition	1.5	1.3	1.3	1.6	-	1.0	1.0
Compression ignition	1.5	-	-	1.1	1.1	1.0	1.0

5.3.5.3 At the request of the manufacturer, the Test Agency may carry out the Type I test before the Type V test has been completed using the deterioration factors in the Table 2 above. On completion of the Type V test, the Test Agency may then amend the type approval results by replacing the deterioration factors in the above table with those measured in the Type V test.

5.3.5.4 Deterioration factors are determined using either procedure in clause 5.3.5.1. of this Chapter or using the values in clause 5.3.5.2. of this Chapter. The factors are used to establish compliance with the requirements of clause 5.3.1 and clause 8.2 (COP) of this Chapter.

5.3.6 On-Board Diagnostics OBD – Test

This test shall be carried out on all vehicles referred in clause 1 of this Chapter. The test procedure described in Chapter 14 of this Part shall be followed.

5.3.7 Free Acceleration Smoke Test

This test shall be carried out on all vehicles referred in Clause1except those vehicles having a positive-ignition engine, vehicles fueled with LPG or NG/biomethane

The test procedure described in Appendix 6 of Chapter 1 of of AIS-137(Part 5) shall be followed.

6.0 MODIFICATION OF THE VEHICLE TYPE

6.1 Every modification of the vehicle type shall be notified to the Test Agency that approved the vehicle type. The Test Agency may then either :

6.1.1 Consider that the modifications made are unlikely to have an appreciable adverse effect and that in any case the vehicle still complies with the requirement; or

6.1.2 Require a further test report from the Test Agency responsible for conducting the tests.

7.0 EXTENSIONS TO TYPE-APPROVALS

7.1 **Extensions For Tailpipe Emissions (Type I, Type II tests)**

7.1.1 Vehicles with Different Reference Masses

7.1.1.1 The type approval shall be extended only to vehicles with a reference mass requiring the use of the next two higher equivalent inertia or any lower equivalent inertia.

7.1.1.2 For category N vehicles, the approval shall be extended to vehicles with a lower reference mass, only if the emissions of the vehicle already approved are within the limits prescribed for the vehicle for which extension of the approval is requested.

7.1.2 Vehicles with Different Overall Transmission Ratios.

7.1.2.1 The type approval shall be extended to vehicles with different transmission ratios only under certain conditions.

7.1.2.2. To determine whether type approval can be extended, for each of the transmission ratios used in the Type I test, the proportion,

$$E = |(V_2 - V_1)|/V_1$$

shall be determined, where, at an engine speed of 1,000 min^{-1}, V_1 is the speed of the type of vehicle approved and V_2 is the speed of the vehicle type for which extension of the approval is requested.

7.1.2.3 If, for each transmission ratio, $E \leq 8$ percent, the extension shall be granted without repeating the Type I test.

7.1.2.4 If, for at least one transmission ratio, $E > 8$ per cent, and if, for each gear ratio, $E \leq 13$ percent, the Type I test shall be repeated. The test may be performed in a laboratory chosen by the manufacturer subject to the approval of the Test Agency. The report of the test shall be sent to the Test Agency responsible for the type approval tests.

7.1.3 Vehicles with Different Reference Masses and Transmission Ratios

The type approval shall be extended to vehicles with different reference masses and transmission ratios, provided that all the conditions prescribed in clause 7.1.1 and 7.1.2 of this Chapter are fulfilled.

7.1.4 Vehicles with Periodically Regenerating Systems

The type approval of a vehicle type equipped with a periodically regenerating system shall be extended to other vehicles with periodically regenerating systems, whose parameters described below are identical, or within the stated tolerances. The extension shall only relate to measurements specific to the defined periodically regenerating system.

7.1.4.1 Identical parameters for extending approval are:

a) Engine;
b) Combustion process;
c) Periodically regenerating system (i.e. catalyst, particulate trap);
d) Construction (i.e. type of enclosure, type of precious metal, type of substrate, cell density);
e) Type and working principle;
f) Dosage and additive system;
g) Volume ±10 per cent;
h) Location (temperature ±50 °C at 90 km/h or 5 % difference of max. temperature/pressure).

7.1.4.2 Use of K_i factors for vehicles with different reference masses

The K_i factors developed by the procedures in Chapter 15 of this Part for type approval of a vehicle type with a periodically regenerating system, may be used by other vehicles which meet the criteria referred to in clause 7.1.4.1. of this Chapter and have a reference mass within the next two higher equivalent inertia classes or any lower equivalent inertia.

7.1.5 Application of Extensions to Other Vehicles

When an extension has been granted in accordance with clauses 7.1.1 to 7.1.4.2 of this Chapter, such a type approval shall not be further extended to other vehicles.

7.2 Extensions for Evaporative Emissions (Type IV Test)

7.2.1 The type approval shall be extended to vehicles equipped with a control system for evaporative emissions which meet the following conditions:

7.2.1.1 The basic principle of fuel/air metering (e.g. single point injection,) is the same.

7.2.1.2 The shape of the fuel tank and the material of the fuel tank and liquid fuel hoses are identical.

7.2.1.3 The worst-case vehicle with regard to the cross-section and approximate hose length shall be tested. Whether non-identical vapour/liquid separators are acceptable is decided by the Test Agency responsible for the type approval tests.

7.2.1.4 The fuel tank volume is within a range of ±10 %.

7.2.1.5 The setting of the fuel tank relief valve is identical.

7.2.1.6 The method of storage of the fuel vapour is identical, i.e. trap form and volume, storage medium, air cleaner (if used for evaporative emission control), etc.

7.2.1.7 The method of purging the stored vapour is identical (e.g. air flow, starts point or purge volume over the preconditioning cycle).

7.2.1.8 The method of sealing and venting the fuel metering system is identical.

7.2.2 The type approval shall be extended to vehicles with:

7.2.2.1 Different engine sizes;

7.2.2.2 Different engine powers;

7.2.2.3 Automatic and manual gearboxes;

7.2.2.4 Two and four wheel transmissions;

7.2.2.5 Different body styles; and

7.2.2.6 Different wheel and tyre sizes.

7.3 Extensions for Durability of Pollution Control Devices (Type V Test)

7.3.1 The type approval shall be extended to different vehicle types, provided that the vehicle, engine or pollution control system parameters specified below are identical or remain within the prescribed tolerances:

7.3.1.1 Vehicle:
Inertia category: the two inertia categories immediately above and any inertia category below.
Total road load at 80 km/h: +5 % above and any value below.

7.3.1.2. **Engine**

(a) Engine cylinder capacity (±15 %);
(b) Number and control of valves;
(c) Fuel system;
(d) Type of cooling system;
(e) Combustion process.

7.3.1.3 Pollution control system parameters:

(a) Catalytic converters and particulate filters:

(i) Number of catalytic converters, filters and elements;
(ii) Size of catalytic converters and filters (volume of monolith ±10 %);
(iii) Type of catalytic activity (oxidizing, three-way, lean NOx trap, SCR, lean NOx catalyst or other);
(iv) Precious metal load (identical or higher);
(v) Precious metal type and ratio (±15 %);
(vi) Substrate (structure and material);
(vii) Cell density; and
(viii) Temperature variation of no more than 50 K at the inlet of the catalytic converter or filter. This temperature variation shall be checked under stabilized conditions at a speed of 90 km/h and the load setting of the Type I test.

(b) Air injection:

(i) With or without;
(ii) Type (puls air, air pumps, other(s)).

(c) EGR

(i). With or without;
(ii). Type (cooled or non-cooled, active or passive control, high pressure or low pressure).

7.3.1.4 The durability test may be carried out using a vehicle, which has a different body style, gear box (automatic or manual) and size of the wheels or tyres, from those of the vehicle type for which the type approval is sought.

7.4 **Extensions for On-Board Diagnostics**

7.4.1 The type approval shall be extended to different vehicles with identical engine and emission control systems as defined in Chapter 2. of this Part The type approval shall be extended regardless of the following vehicle characteristics:

(a) Engine accessories;
(b) Tyres;
(c) Equivalent inertia;
(d) Cooling system;
(e) Overall gear ratio;
(f) Transmission type; and
(g) Type of body work

7.4.2 In a vehicle model, which is previously approved for OBD parameter, if there is any change in OBD parameter, then the testing for the changed OBD parameter only needs to be conducted as mutually agreed between the test agency and vehicle manufacturer if manufacturer can prove that changed OBD parameter don't have any interaction with other OBD parameters.

8.0 CONFORMITY OF PRODUCTION (COP)

8.1 Every produced vehicle of the model approved under this Part shall conform, with regard to components affecting the emission of gaseous and particulate pollutants by the engine, emissions from the crankcase & Evaporative emissions, to the vehicle model type approved. The administrative procedure for carrying out conformity of production is given in AIS-137(Part 6). However, when the period between commencement of production of a new model and beginning of next rationalized COP period is less than two months, the same would be merged with the rationalized COP period.

8.1.1 Where applicable the tests of Types I, II, III, IV and the test for OBD shall be performed, as described in Table 1 of this Chapter. The specific procedures for conformity of production are set out in the paragraphs 8.2 onward.

8.2 Checking the Conformity of the Vehicle for a Type I Test

8.2.1 The Type I test shall be carried out on a vehicle of the same specification as described in the type approval certificate. When a Type I test is to be carried out and a vehicle type-approval has one or several extensions, the Type I tests will be carried out either on the vehicle described in the initial information package or on the vehicle described in the information package relating to the relevant extension.

8.3 Three vehicles are selected at random in the series and are tested as described in clause 5.3 of this Chapter. Vehicles offered for Type I test will be tested in accordance with their declared weight applicable Inertia class.

However, in case of vehicle model and its variants produced less than 250 in the half yearly period as mentioned in clause 3.1.1 of AIS-137 (Part 6) sample size shall be one. The deterioration factors are used in the same way. The limit values are as specified in applicable Gazette Notification.

8.4 Type I Test: Verifying the average emission of gaseous pollutants: For verifying the conformity of production in a Type I test, the following procedure as per Option 1 is adopted.

8.5 To verify the average tailpipe emissions of gaseous pollutants of low volume vehicles with annual production less than 250 per 6 months, manufacture can choose from the Option 1 OR Option 2 as listed below:

8.6 Option 1

8.6.1 The vehicle samples taken from the series, as described in 8.1 of this Chapter is subjected to the test described in clause 5.3.1 of this Chapter. The results shall be multiplied by the deterioration factors used at the time of type approval and in the case of periodically regenerating systems multiplicative or additive Ki factor shall be applied to the results obtained by the procedure specified in Chapter 15 of this Part at the time when type approval was granted. The result masses of gaseous emissions and in addition in case of vehicles equipped with compression ignition engines and GDI Gasoline engines, the mass of particulates and particulate numbers obtained in the test shall not exceed the applicable limits.

8.6.2 Procedure for Conformity of Production for all M and N Category vehicles upto 3,500 kg GVW.

8.6.2.1 Conformity of production shall be verified as per Gazette notification and with the procedure given below.

8.6.2.2 To verify the average tailpipe emissions of gaseous pollutants following procedure shall be adopted:

8.6.2.3 Minimum of three vehicles shall be selected randomly from the series with a sample lot size as defined in AIS-137 (Part 6)

8.6.2.4 After selection by the Test Agency; the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in AIS-137(Part 6).

8.6.2.5 All three randomly selected vehicles shall be tested for a Type I test as per clause 5.3.1 of this Chapter.

8.6.2.6 Let X_{i1}, X_{i2} & X_{i3} are the test results for the sample No.1, 2 and 3.

8.6.2.7 If the natural Logarithms of the measurements in the series are X_1, X_2, X_3 .... X_j and L_i is the natural logarithm of the limit value for the pollutant, then define:

$$d_j = X_j - L_i$$

$$\bar{d}_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^2 = \frac{1}{n}\sum_{j=1}^{n}\left(d_j - \bar{d}_n\right)^2$$

Table 3 of this Chapter shows values of the pass (A_n) and fail (B_n) decision numbers against current sample number. The test statistic is the ratio d_n / V_n and must be used to determine whether the series has passed or failed as follows:

- Pass the series, if $\bar{d}_n/V_n \leq A_n$ for all the pollutants.
- Fail the series if $\bar{d}_n/V_n \geq B_n$ for any one of the pollutants.
- Increase the sample size by one, if $A_n < \bar{d}_n/V_n < B_n$ for any one of the pollutants.

If no pass decision is reached for all the pollutants and no fail decision is reached for one pollutant, a test shall be carried out on another randomly selected sample till a pass or fail decision is arrived at (See Figure 2 of this Chapter).

8.6.2.9 Running in may be carried out at the request of the manufacturer either as per the manufacturers recommendation submitted during type approval or with a maximum of 3000 km for the vehicles equipped with a positive ignition engine and with a maximum of 15000 km for the vehicles equipped with a compression ignition engine.

8.6.2.10 Alternatively if the manufacturer wishes to run in the vehicles, ("x" km, where x ≤ 3000 km for vehicles equipped with a positive ignition engine and x ≤ 15000 km for vehicles equipped with a compression ignition engine), the procedure will be as follows:

- the pollutant emissions (type I) will be measured at zero and at "x" km on the first tested vehicle,
- the evolution coefficient of the emissions between zero and "x" km will be calculated for each of the pollutants:

$$\frac{Emissions\ "x"\ km}{Emissions\ zero\ km}$$

This may be less than 1,

- the other vehicles will not be run in, but their zero km emissions will be multiplied by the evolution coefficient.

In this case, the values to be taken will be:

- the values at "x" km for the first vehicle,
- the values at zero km multiplied by the evolution coefficient for the other vehicles.

Evolution coefficient derived will be applicable for that particular selected COP period only

8.6.2.11 All these tests shall be conducted with the reference fuel as specified in the applicable gazette notification. However, at the manufacturer's request, tests may be carried out with commercial fuel.

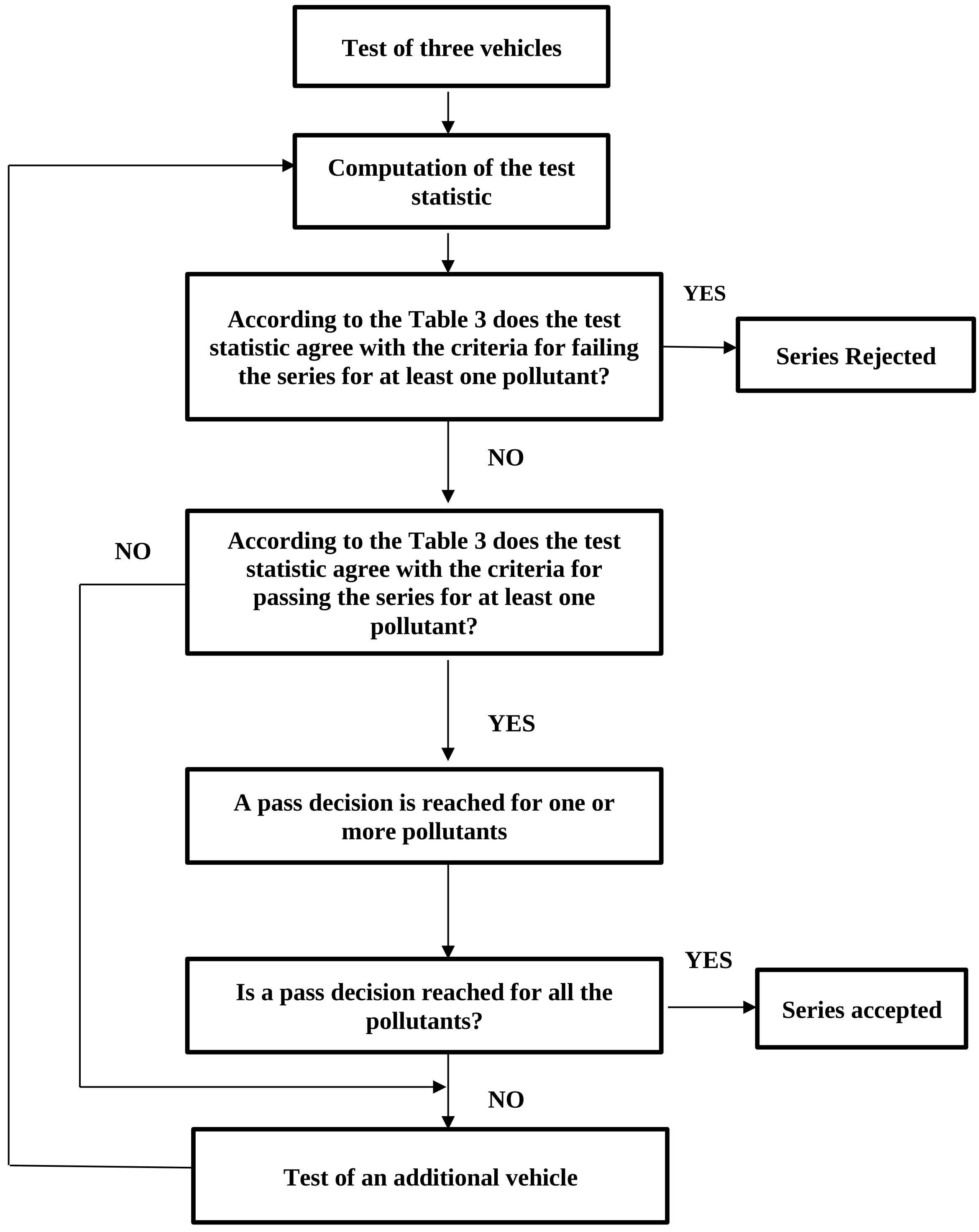


Figure 2
Option 1 CoP Test Procedure

Table 3
Applicable for CoP Procedure

Sample size (n)	Pass decision threshold (A_n)	Fail decision threshold (B_n)
3	-0.80381	16.64743
4	-0.76339	7.68627
5	-0.72982	4.67136
6	-0.69962	3.25573
7	-0.67129	2.45431
8	-0.64406	1.94369
9	-0.61750	1.59105
10	-0.59135	1.33295
11	-0.56542	1.13566
12	-0.53960	0.97970
13	-0.51379	0.85307
14	-0.48791	0.74801
15	-0.46191	0.65928
16	-0.43573	0.58321
17	-0.40933	0.51718
18	-0.38266	0.45922
19	-0.35570	0.40788
20	-0.32840	0.36203
21	-0.30072	0.32078
22	-0.27263	0.28343
23	-0.24410	0.24943
24	-0.21509	0.21831
25	-0.18557	0.18970
26	-0.15550	0.16328
27	-0.12483	0.13880
28	-0.09354	0.11603
29	-0.06159	0.09480
30	-0.02892	0.07493
31	0.00449	0.05629
32	0.03876	0.03876

8.7 **Option 2**

8.7.1 The vehicle samples taken from the series, as described in 8.1 is subjected to the test described in clause 5.3.1 of this Chapter. The results shall be multiplied by the deterioration factors used at the time of type approval and in the case of periodically regenerating systems multiplicative or additive Ki factor must be applied to the results obtained by the procedure specified in Chapter 15 of this Part at the time when type approval was granted. The result masses of gaseous emissions and in addition in case of vehicles equipped with compression-ignition engines and Gasoline GDI engines, the mass of particulates and particulate numbers obtained in the test shall not exceed the applicable limits.

8.7.2 Procedure for Conformity of Production for all M and N Category vehicles upto 3,500 kg GVW.

8.7.2.1 Conformity of production shall be verified as per Gazette Notification and with the procedure given below.

8.7.2.2 To verify the average tailpipe emissions of gaseous pollutants following procedure shall be adopted:

8.7.2.3 Minimum of three vehicles shall be selected randomly from the series with a sample lot size.

8.7.2.4 After selection by the authority, the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in AIS-137 (Part 6)

8.7.2.5 First vehicle out of three randomly selected vehicles shall be tested for Type I test as per clause 5.3.1 of this Chapter

8.7.2.6 Only one test (V_1) shall be performed if the test results for all the pollutants meet 70 % of their respective limit values (i.e. $V_1 \leq 0.7L$ and L being the COP Limit)

8.7.2.7. Only two tests shall be performed if the first test results for all the pollutants doesn't exceed 85% of their respective COP limit values (i.e. $V_1 \leq 0.85L$) and at the same time one of these pollutant value exceeds 70% of the limit (i.e. $V_1 > 0.7L$) In addition, to reach the pass decision for the series, combined results of V_1 & V_2 shall satisfy such requirement that: $(V_1 + V_2) < 1.70L$ and $V_2 \leq L$ for all the pollutants.

8.7.2.8 Third Type - I (V_3) test shall be performed if the clause 8.7.2.7 of this Chapter does not satisfy and if the second test results for all pollutants are within the 110% of the prescribed COP limits, Series passes only if the arithmetical mean for all the pollutants for three Type I tests doesn't exceed their respective limit value (i.e. $(V_1 + V_2 + V_3) / 3 < L$)

8.7.2.9 If one of the three test results obtained for any one of the pollutants exceed 10% of their respective limit values the test shall be continued on sample No. 2 and 3 as given in the Figure 2 of this Chapter, as the provision for extended COP and shall be informed by the Test Agency to the Nodal Agency.

8.7.2.10 These randomly selected sample No. 2 and 3 shall be tested for only one Type-I test as per clause 5.3.1 of this Chapter.

8.7.2.11 Let X_{i2} & X_{i3} are the test results for the sample No.2 and 3 and Xi1 is the test result of the Sample No.1 which is the arithmetical mean for the three Type - I test conducted on Sample No. 1.

8.2.7.12 If the natural Logarithms of the measurements in the series are X_1, X_2, X_3..........X_j and L_i is the natural logarithm of the limit value for the pollutant, then define :

$$d_j = X_j - L_i$$

$$\bar{d}_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^2 = \frac{1}{n}\sum_{j=1}^{n} \left(d_j - \bar{d}_n\right)^2$$

8.7.2.13 Table 3 of this Chapter shows values of the pass (An) and fail (Bn) decision numbers against current sample number. The test statistic is the ratio $\bar{d}_n / V_n$ and must be used to determine whether the series has passed or failed as follows :

- Pass the series, $\bar{d}_n / V_n \leq A_n$ for all the pollutants
- Fail the series $\bar{d}_n / V_n \geq B_n$ for any one of the pollutants
- Increase the sample size by one, if $A_n < \bar{d}_n / V_n < B_n$ for any one of the pollutants.

8.7.2.14 If no pass decision is reached for all the pollutants and no fail decision is reached for one pollutant, a test shall be carried out on another randomly selected sample till a pass or fail decision is arrived at (See Figure 3 of this Chapter).

8.8 All these tests shall be conducted with the reference fuel as specified in the applicable gazette notification. However, at the manufacturer's request, tests may be carried out with commercial fuel.

8.9 Type II Test: Carbon monoxide and Hydrocarbons emission at idling speed. When the vehicle taken from the series for the first Type I test mentioned in clause 8.2 of this Chapter, subjected to the test described in Chapter 9 of this Part for verifying the carbon monoxide and hydrocarbon emission at idling speed should meet the limit values specified in Gazette notification. If it does not, another 10 vehicles shall be taken from the series at random and shall be tested as per Chapter 9 of this Part. These vehicles can be same as those selected for carrying out Type I test. Additional vehicles if required shall be selected for carrying out for Type II test. At least 9 vehicles should meet the limit values specified in clause 5.3.2 of this Chapter. Then the series is deemed to conform.

8.10 For Type III test is to be carried out, it must be conducted on all vehicles selected for Type I CoP test. The conditions laid down in 5.3.3 of this Chapter must be complied with.

8.11 For Type IV test is to be carried out, it must be conducted in accordance with clause 7 of Chapter 11 of this Part.

8.12 Free Acceleration Smoke Test : Test is to be carried out on vehicles equipped with Compression ignition engines, it must be conducted on all vehicles selected for Type I COP test and should meet the limit values specified in Gazette Notification. Test to be carried out in accordance with Appendix 6 of Chapter 1 of AIS-137(Part 5). If it does not meet the limit values specified in Gazette Notification, then procedure shall be followed as per clause 6 of Chapter 5 of AIS-137(Part 5)

8.13 **Checking the conformity of the vehicle for On-board Diagnostics (OBD)**

8.13.1 If a verification of the performance of the OBD system is to be carried out, it shall be conducted in accordance with the following requirements:

8.13.1.1 When the Test Agency determines that the quality of production seems unsatisfactory, a vehicle shall be randomly taken from the series and subjected to the tests described in Appendix 1 of Chapter 14 of this Part.

8.13.1.2 The production shall be deemed to conform if this vehicle meets the requirements of the tests described in Appendix 1 of Chapter 14 of this Part.

8.13.1.3 If the vehicle taken from the series does not satisfy the requirements of clause 8.13.1.1.of this Chapter, a further random sample of four vehicles shall be taken from the series and subjected to the tests described in Appendix 1 of Chapter 14 of this Part. The tests may be carried out on vehicles which have been run in for no more than 15,000 km.

8.13.1.4 The production shall be deemed to conform if at least three vehicles meet the requirements of the tests described in Appendix 1 of Chapter 14 of this Part.

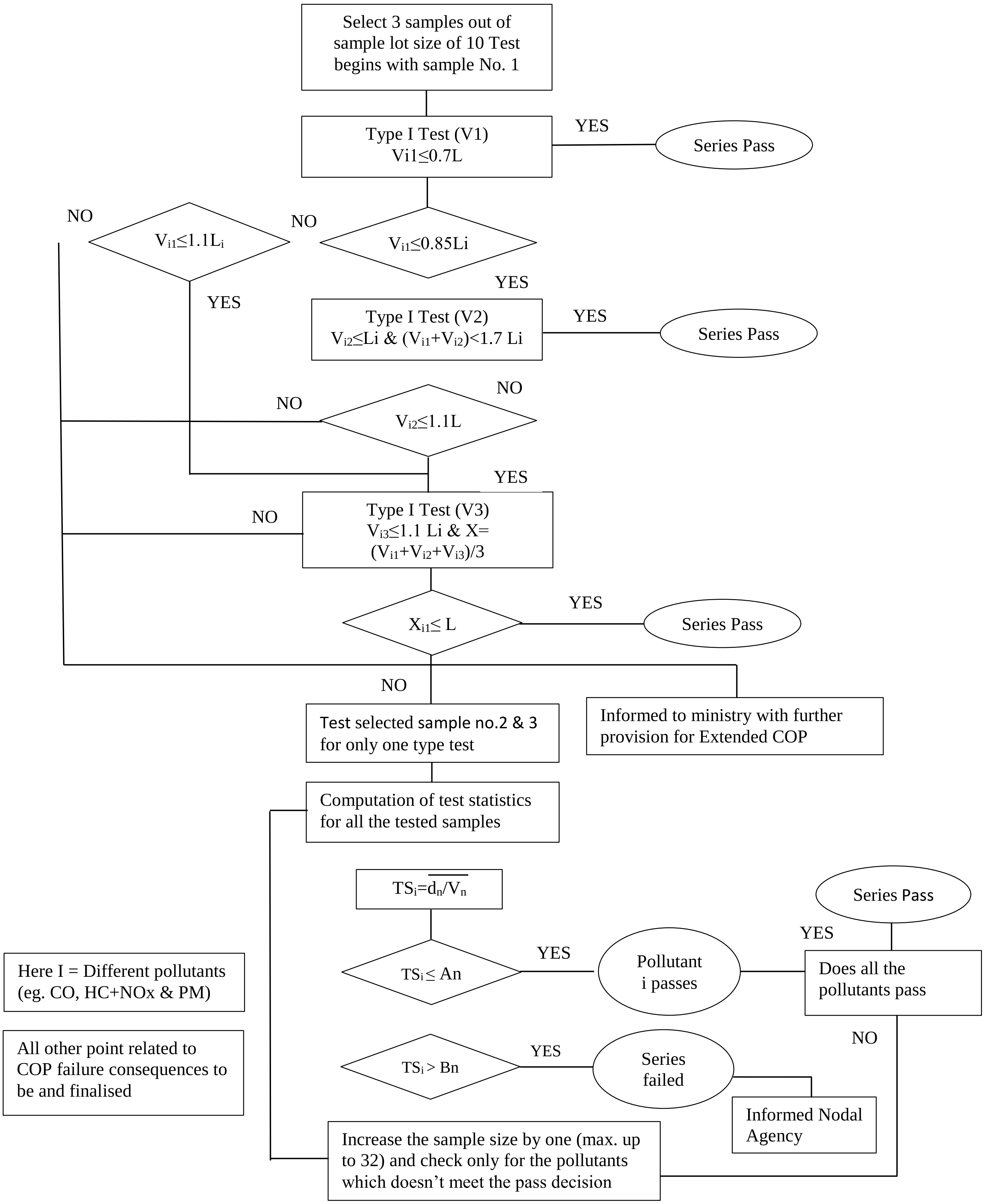


Figure 3
OPTION 2: COP Test Procedure

9.0 IN - SERVICE CONFORMITY

9.1 **Introduction**

This clause sets out the tailpipe emissions and OBD (including $IUPR_M$) in-service conformity requirements for vehicles type approved to this Part.

9.2 **In-service conformity**

9.2.1 The in-service conformity by the Test Agency shall be conducted on the basis of any relevant information that the manufacturer has, under the same procedures as those for the conformity of production. .

9.2.2 Figures 1 and 2 of Appendix 2 of Chapter 18 of this Part illustrate the procedure for in-service conformity checking. The process for in-service conformity is described in Appendix 3 of Chapter 18 of this Part.

9.2.3 As part of the information provided for the in-service conformity control, at the request of the Test Agency, the manufacturer shall report to the Test Agency on warranty claims, warranty repair works and OBD faults recorded at servicing, according to a format agreed at type approval. The information shall detail the frequency and substance of faults for emissions related components and systems. The reports shall be filed at least once a year for each vehicle model for the duration of the period of up to 5 years of age or 100,000 km, whichever is the sooner.

9.2.4 Parameters Defining the In-Service Family
The in-service family may be defined by basic design parameters which shall be common to vehicles within the family. Accordingly, vehicle types may be considered as belonging to the same in-service family if they have in common, or within the stated tolerances, the following parameters:

9.2.4.1 Combustion process (two stroke, four stroke, rotary);

9.2.4.2 Number of cylinders;

9.2.4.3 Configuration of the cylinder block (in-line, V, radial, horizontally opposed, other). The inclination or orientation of the cylinders is not a criterion;

9.2.4.4 Method of engine fueling (e.g. indirect or direct injection);

9.2.4.5 Type of cooling system (air, water, oil);

9.2.4.6 Method of aspiration (naturally aspirated, pressure charged);

9.2.4.7 Fuel for which the engine is designed (gasoline, diesel, NG/biomethane, LPG, etc.). Bi-fueled vehicles may be grouped with dedicated fuel vehicles providing one of the fuels is common;

9.2.4.8 Type of catalytic converter (three-way catalyst, lean NO_X trap, SCR, lean NO_X catalyst or other(s));

9.2.4.9 Type of particulate trap (with or without);

9.2.4.10 Exhaust gas recirculation (with or without, cooled or non-cooled); and

9.2.4.11 Engine cylinder capacity of the largest engine within the family minus 30 %

9.2.5 Information Requirements

In-service conformity will be conducted by the Teat Agency on the basis of information supplied by the manufacturer. Such information shall include in particular, the following:

9.2.5.1 The name and address of the manufacturer;

9.2.5.2 The name, address, telephone and fax numbers and e-mail address of the authorized representative within the areas covered by the manufacturer's information;

9.2.5.3 The model name(s) of the vehicles included in the manufacturer's information;

9.2.5.4 Where appropriate, the list of vehicle types covered within the manufacturer's information, i.e., for tailpipe emissions, the in-service family group in accordance with clause 9.2.4. of this Chapter and, for OBD and $IUPR_M$, the OBD family, in accordance with Appendix 2 of Chapter 14 of this Part;

9.2.5.5 The vehicle identification number (VIN) codes applicable to these vehicle types within the family (VIN prefix);

9.2.5.6 The numbers of the type approvals applicable to these vehicle types within the family, including, where applicable, the numbers of all extensions and field fixes/recalls re-works);

9.2.5.7 Details of extensions, field fixes/recalls to those type approvals for the vehicles covered within the manufacturer's information (if requested by the Test Agency);

9.2.5.8 The period of time over which the manufacturer's information was collected;

9.2.5.9 The vehicle build period covered within the manufacturer's information (e.g. vehicles manufactured during the 2018 calendar year);

9.2.5.10 In-service conformity checking procedure, including:

(a) Vehicle location method;
(b) Vehicle selection and rejection criteria;
(c) Test types and procedures used for the programme;
(d) The manufacturer's acceptance/rejection criteria for the in-service family group;

(e) Geographical area(s) within which the manufacturer has collected information; and
(f) Sample size and sampling plan used.

9.2.5.11 The results in-service conformity procedure, including:

(a) Identification of the vehicles included in the programme (whether tested or not). The identification shall include the following:
  (i) Model name;
  (ii) Vehicle Identification Number (VIN);
  (iii) Vehicle registration number;
  (iv) Date of manufacture;
  (v) Region of use (where known); and
  (vi) Tyres fitted (tailpipe emissions only).

(b) The reason(s) for rejecting a vehicle from the sample;

(c) Service history for each vehicle in the sample (including any re-works);

(d) Repair history for each vehicle in the sample (where known); and

(e) Test data, including the following:
  (i) Date of test/download;
  (ii) Location of test/download; and
  (iii) Distance indicated on vehicle odometer; for tailpipe emissions only;
  (iv) Test fuel specifications (e.g. test reference fuel or market fuel);
  (v) Test conditions (temperature, humidity, dynamometer inertia weight);
  (vi) Dynamometer settings (e.g. power setting); and
  (vii) Test results (from at least three different vehicles per family); and, for $IUPR_M$ only:
  (viii) All required data downloaded from the vehicle; and
  (ix) For each monitor to be reported the in-use performance ratio $IUPR_M$.

9.2.5.12 Records of indication from the OBD system.

9.2.5.13 For $IUPR_M$ sampling, the following:

(a) The average of in-use-performance ratios $IUPR_M$ of all selected vehicles for each monitor according to clauses 7.1.4. and 7.1.5. of Appendix 1 of Chapter 14 of this Part;

(b) The percentage of selected vehicles, which have an $IUPR_M$ greater or equal to the minimum value applicable to the monitor according to clauses 7.1.4. and 7.1.5. of Appendix 1 of Chapter 14 of this Part.

9.3 **Selection of Vehicles for In-Service Conformity**

9.3.1 The information gathered by the manufacturer shall be sufficiently comprehensive to ensure that in-service performance can be assessed for normal conditions of use. The sampling shall be drawn from at least two regions with substantially different vehicle operating conditions. Factors such as differences in fuels, ambient conditions, average road speeds, and urban/highway driving split shall be taken into consideration in the selection of the regions.

For OBD $IUPR_M$ testing only, vehicles fulfilling the criteria of clause 2.2.1. of Appendix 1 of Chapter 18 of this Part shall be included in the test sample.

9.3.2 In selecting the regions for sampling vehicles, vehicles may be selected from a region that is considered to be particularly representative. Selection should be representative (e.g. by the market having the largest annual sales of a vehicle family within the applicable region). When a family requires more than one sample lot to be tested, as defined in clause 9.3.5. of this Chapter, the vehicles in the second and third sample lots shall reflect different vehicle operating conditions from those selected for the first sample.

9.3.3 The emissions testing to be done at a Test Agency or tests can be conducted on manufacturer's test facility which is accredited by NABL as per ISO 17025.

9.3.4 The in-service tailpipe emissions conformity tests shall be continuously carried out reflecting the production cycle of applicable vehicles types within a given in-service vehicle family. The maximum time period between commencing two in-service conformity checks shall not exceed 18 months. In the case of vehicle types covered by an extension to the type approval that did not require an emissions test, this period may be extended up to 24 months.

9.3.5 Sample Size

9.3.5.1 When applying the statistical procedure defined in Appendix 2 of Chapter 18 of this Part (i.e. for tailpipe emissions), the number of sample lots shall depend on the annual sales volume of an in-service family as defined in Table 4 of this Chapter.

Table 4
Sample Size

- Production volume - per calendar year (for tailpipe emission tests), - of vehicles of an OBD family with IUPR in the sampling period	Number of sample lots
Up to 100,000	1
100,001 to 200,000	2
Above 200,000	3

9.3.5.2 For IUPR, the number of sample lots to be taken is described in Table 4 of this Chapter and is based on the number of vehicles of an OBD family that are approved with IUPR (subject to sampling).

For the first sampling period of an OBD family, all of the vehicle types in the family that are approved with IUPR shall be considered to be subject to sampling. For subsequent sampling periods, only vehicle types which have not been previously tested or are covered by emissions approvals that have been extended since the previous sampling period shall be considered to be subject to sampling.

For families consisting of fewer than 5,000 registrations that are subject to sampling within the sampling period, the minimum number of vehicles in a sample lot is six. For all other families, the minimum number of vehicles in a sample lot to be sampled is fifteen.

Each sample lot shall adequately represent the sales pattern, i.e. at least the high volume vehicle types (≥20 per cent of the family total) shall be represented.

Vehicles of small series productions with less than 1000 vehicles per OBD family are exempted from minimum IUPR requirements as well as the requirements to demonstrate these to the Test Agency.

9.4 On the basis of clause 9.2., the Test Agency shall adopt one of the following decisions and actions:

(a) Decide that the in-service conformity of a vehicle type, vehicle in- service family or vehicle OBD family is satisfactory and not take any further action;

(b) Decide that the data is insufficient to reach a decision and request additional information or vehicles

(c) Decide that based on data of testing programmes, whether it is insufficient to reach a decision and request additional information or vehicles

(d) Decide that the in-service conformity of a vehicle type, that is part of an in-service family, or of an OBD family, is unsatisfactory and proceed to have such vehicle type or OBD family tested in accordance with Appendix 1 of Chapter 18 of this Part.

If, according to the $IUPR_M$ audit, the test criteria of clause 6.1.2., sub-clause (a) of Appendix 1 of Chapter 18 of this Part are met for the vehicles in a sample lot, the Test Agency shall take the further action described in sub-clause (d) above.

9.4.1 Where Type I test are considered necessary to check the conformity of emission control devices with the requirements for their performance while in service, such tests shall be carried out using a test procedure meeting the statistical criteria defined in Appendix 2 of Chapter 18 of this Part.

9.4.2 The Test Agency, in cooperation with the manufacturer, shall select a sample of vehicles with sufficient mileage whose use under normal conditions can be reasonably assured. The manufacturer shall be consulted on the choice of the vehicles in the sample and allowed to attend the confirmatory checks of the vehicles.

9.4.3 The manufacturer shall be authorized, under the supervision of the Test Agency, to carry out checks, even of a destructive nature, on those vehicles with emission levels in excess of the limit values with a view to establishing possible causes of deterioration which cannot be attributed to the manufacturer (e.g. use of leaded gasoline before the test date). Where the results of the checks confirm such causes, those test results shall be excluded from the conformity check.

10.0 PRODUCTION DEFINITIVELY DISCONTINUED

If the holder of the approval completely ceases to manufacture a type of vehicle approved in accordance with this Part, he shall so inform the Test Agency which granted the approval.

CHAPTER 1 - APPENDIX 1

MANUFACTURER'S CERTIFICATE OF COMPLIANCE WITH THE OBD IN -USE PERFORMANCE REQUIREMENTS

Manufacturer:

Address of the manufacturer:

Certifies that:

1. The vehicle types listed in attachment to this Certificate are in compliance with the provisions of clause 7.0 of Appendix 1 of Chapter 14 of this Part relating to the in-use performance of the OBD system under all reasonably foreseeable driving conditions;

2. The plan(s) describing the detailed technical criteria for incrementing the numerator and denominator of each monitor attached to this certificate are correct and complete for all types of vehicles to which this certificate applies.

Done at [……Place]
On […….Date]

[Signature of the Manufacturer's Representative]

Annexes:

(a) List of vehicle types to which this Certificate applies;

(b) Plan(s) describing the detailed technical criteria for incrementing the numerator and denominator of each monitor, as well as plan(s) for disabling numerators, denominators and general denominator.

CHAPTER 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

1.0 Vehicle manufacturers shall provide essential characteristics of the vehicle and engine and information concerning the conduct of tests as per AIS-007, as amended from time to time.

CHAPTER 3

TYPE I TEST
VERIFYING EXHAUST EMISSIONS
AFTER A COLD START

1.0 INTRODUCTION

This Chapter describes the procedure for the Type I test. When the reference fuel to be used is LPG or NG/biomethane, the provisions of Chapter 13 of this Part shall apply additionally.

2.0 TEST CONDITIONS

2.1 **Ambient Conditions**

2.1.1 During the test, the test cell temperature shall be between 293 K and 303 K (20°C and 30°C). The absolute humidity (H) of either the air in the test cell or the intake air of the engine shall be such that:

$5.5 \leq H \leq 12.2$ (g H_2O/kg dry air)

The absolute humidity (H) shall be measured.

The following temperatures shall be measured:

Test cell ambient air,

Dilution and sampling system temperatures as required for emissions measurement systems defined in Appendix 2 of Chapter 4, Chapter 7 and Chapter 8 of this Part

The atmospheric pressure shall be measured.

2.2 **Test Vehicle**

2.2.1 The vehicle shall be presented in good mechanical condition. It shall have been run-in and driven at least 3,000 km before the test.

2.2.2 The exhaust device shall not exhibit any leak likely to reduce the quantity of gas collected, which quantity shall be that emerging from the engine.

2.2.3 The tightness of the intake system may be checked to ensure that carburetion is not affected by an accidental intake of air.

2.2.4 The settings of the engine and of the vehicle's controls shall be those prescribed by the manufacturer. This requirement also applies, in particular, to the settings for idling (rotation speed and carbon monoxide content of the exhaust gases), for the cold start device and for the exhaust gas cleaning system.

2.2.5 The vehicle to be tested, or an equivalent vehicle, shall be fitted, if necessary, with a device to permit the measurement of the characteristic parameters necessary for chassis dynamometer setting, in conformity with clause 4. of this Chapter.

2.2.6 The Test Agency responsible for the tests may verify that the vehicle's performance conforms to that stated by the manufacturer, that it can be used for normal driving and, more particularly, that it is capable of starting when cold and when hot.

2.2.7 The daytime running lamps of the vehicle, as applicable and defined in AIS-008 shall be switched on during the test cycle. The vehicle tested shall be equipped with the daytime running lamp system that has the highest electrical energy consumption among the daytime running lamp systems, which are fitted by the manufacturer to vehicles in the group represented by the type-approved vehicle. The manufacturer shall supply appropriate technical documentation to Test Agency in this respect.

2.3 **Test Fuel**

2.3.1 The appropriate reference fuel as defined in said Gazette Notification shall be used for testing.

2.3.2 Vehicles that are fueled either with gasoline or with LPG or NG/biomethane shall be tested according to Chapter 13 of this Part.

2.4 **Vehicle Installation**

2.4.1 The vehicle shall be approximately horizontal during the test so as to avoid any abnormal distribution of the fuel.

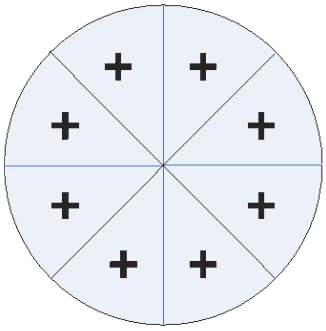
2.4.2 A current of air of variable speed shall be blown over the vehicle. The blower speed shall be, within the operating range of 10 km/h to at least the maximum speed of the test cycle being used. The linear velocity of the air at the blower outlet shall be within ±5 km/h of the corresponding roller speed within the range of 10 km/h to 50 km/h. At the range over 50 km/h, the linear velocity of the air shall be within ±10 km/h of the corresponding roller speed. At roller speeds of less than 10 km/h, air velocity may be zero.

The above mentioned air velocity shall be determined as an averaged value of a number of measuring points which:

(a) For blowers with rectangular outlets are located at the centre of each rectangle dividing the whole of the blower outlet into 9 areas (dividing both horizontal and vertical sides of the blower outlet into 3 equal parts). The center area shall not be measured (as shown in the diagram below).

+	+	+
+		+
+	+	+

(b) For circular blower outlets, the outlet shall be divided into 8 equal arcs by vertical, horizontal and 45° lines. The measurement points lie on the radial center line of each arc (22.5°) at a radius of two thirds of the total (as shown in the diagram below).



These measurements shall be made with no vehicle or other obstruction in front of the fan.

The device used to measure the linear velocity of the air shall be located at between 0 and 20 cm from the air outlet.

The final selection of the blower shall have the following characteristics:

(a) Area: at least 0.2 m^2;
(b) Height of the lower edge above ground: approximately 0.2 m;
(c) Distance from the front of the vehicle: approximately 0.3 m.

The height and lateral position of the cooling fan may be modified at the request of the manufacturer and if considered appropriate by the Test Agency.

In the cases described above, the cooling fan position and configuration shall be recorded in the approval test report and shall be used for conformity of production (COP) and in-service conformity (ISC) testing.

3.0 TEST EQUIPMENT

3.1 **Chassis Dynamometer**

The chassis dynamometer requirements are given in Appendix 1 of Chapter 4 of this Part.

3.2 **Exhaust Dilution System**

The exhaust dilution system requirements are given in Appendix 2 of Chapter 4 of this Part.

3.3 **Gaseous Emissions Sampling and Analysis**

The gaseous emissions sampling and analysis equipment requirements are given in Chapter 7 of this Part.

3.4 **Particulate Mass (PM) Emissions Equipment**

The particulate mass sampling and measurement requirements are given in Appendix 1of Chapter 8 of this Part.

3.5 **Particle Number (PN) Emissions Equipment**

The particle number sampling and measurement requirements are given in Appendix 2 of Chapter 8 of this Part.

3.6 **General Test Cell Equipment**

The following temperatures shall be measured with an accuracy of ±1.5 K:

(a) Test cell ambient air;
(b) Intake air to the engine;
(c) Dilution and sampling system temperatures as required for emissions measurement systems defined in Appendix 2 of Chapter 4, Chapter 7 and Chapter 8 of this Part

The atmospheric pressure shall be measurable to within ± 0.1 kPa.

The absolute humidity (H) shall be measurable to within ± 5 percent.

4.0 DETERMINATION OF VEHICLE ROAD LOAD

4.1 **Test Procedure**

The procedure for measuring the vehicle road load is described in Appendix 2 of Chapter 5 of this Part.

This procedure is not required if the chassis dynamometer load is to be set according to the reference mass of the vehicle.

5.0 EMISSIONS TEST PROCEDURE

5.1 **Test Cycle**

The operating cycle, made up of a Part One (urban cycle) and Part Two (extra-urban cycle), is illustrated in Figure 3 of this Chapter. During the complete test the elementary urban cycle is run four times followed, by Part Two.

5.2 Use of the Gearbox

5.2.1 If the maximum speed which can be attained in first gear is below 15 km/h, the second, third and fourth gears shall be used for the urban cycle (Part One) and the second, third, fourth and fifth gears for the extra-urban cycle (Part Two). The second, third and fourth gears may also be used for the urban cycle (Part One) and the second, third, fourth and fifth gears for the extra urban cycle (Part Two) when the manufacturer's instructions recommend starting in second gear on level ground, or when first gear is therein defined as a gear reserved for cross-country driving, crawling or towing.

Vehicles which do not attain the acceleration and maximum speed values required in the operating cycle shall be operated with the accelerator control fully depressed until they once again

reach the required operating curve. Deviations from the operating cycle shall be recorded in the test report.

Vehicles equipped with semi-automatic-shift gearboxes shall be tested by using the gears normally employed for driving, and the gear shift is used in accordance with the manufacturer's instructions.

5.2.2 Vehicles equipped with automatic-shift gearboxes shall be tested with the highest gear ("Drive") engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order. Furthermore, the gear-change points shown in Table 2 and Table 3 of this Chapter shall not apply; acceleration shall continue throughout the period represented by the straight line connecting the end of each period of idling with the beginning of the next following period of steady speed. The tolerances given in clauses 5.2.4 and 5.2.5 of this Chapter shall apply.

5.2.3 Vehicles equipped with an overdrive that the driver can actuate shall be tested with the overdrive out of action for the urban cycle (Part One) and with the overdrive in action for the extra-urban cycle (Part Two).

5.2.4 A tolerance of ±2 km/h shall be allowed between the indicated speed and the theoretical speed during acceleration, during steady speed, and during deceleration when the vehicle's brakes are used. If the vehicle decelerates more rapidly without the use of the brakes, only the provisions of clause 6.11.4.3 of this Chapter shall apply. Speed tolerances greater than those prescribed shall be accepted during phase changes provided that the tolerances are never exceeded for more than 0.5 s on any one occasion.

5.2.5 The time tolerances shall be ±1.0 s. The above tolerances shall apply equally at the beginning and at the end of each gear-changing period for the urban cycle (Part One) and for the operations Nos. 3, 5 and 7 of the extra-urban cycle (Part Two). It should be noted that the time of two seconds allowed includes the time for changing gear and, if necessary, a certain amount of latitude to catch up with the cycle.

6.0 TEST PREPARATION

6.1 Load and Inertia Setting

6.1.1 Load Determined with Vehicle Road Test

The dynamometer shall be adjusted so that the total inertia of the rotating masses will simulate the inertia and other road load forces acting on the vehicle when driving on the road. The means by which this load is determined is described in clause 4. of this Chapter

Load and inertia adjustment to be carried out with vehicle mounting on the chassis dynamometer with proper vehicle warm up as per manufacturer recommendation before vehicle preconditioning cycle. Derived load set values shall be used for vehicle preconditioning and for mass emission test.

Dynamometer with fixed load curve: the load simulator shall be adjusted to absorb the power exerted on the driving wheels at a steady speed of 80 km/h and the absorbed power at 50 km/h shall be noted.

Dynamometer with adjustable load curve: the load simulator shall be adjusted in order to absorb the power exerted on the driving wheels at steady speeds of 90, 80, 60 and 40 and 20 km/h.

6.1.2 Load Determined by Vehicle Reference Mass

With the manufacturer's agreement the following method may be used.

The brake is adjusted so as to absorb the load exerted at the driving wheels at a constant speed of 80 km/h, in accordance with Table 1 of this Chapter.

If the corresponding equivalent inertia is not available on the dynamometer, the larger value closest to the vehicle reference mass will be used.

In the case of vehicles other than passenger cars, with a reference mass of more than 1,700 kg or vehicles with permanent all-wheel drive, the power values given in Table 1 of this Chapter are multiplied by a factor 1.3.

In case of 4x2 and 4x4 vehicles as variants, if declared CO_2 is

- same for both 4x4 and 4x2, test will be carried out in 4x4 variant.
- is different for 4x4 and 4x2 variants, test will be carried out on both variants.

However, for vehicle model having a selectable option for 4x2 and 4x4 modes, test will be carried out in 4x2 mode unless opted otherwise by the vehicle manufacturer.

Table 1
Setting of the Dynamometer (Alternative Method)

Reference Mass of Vehicles		Equivalent Inertia	Power and load absorbed by dynamometer at 80 km/h		Coefficients	
					A	B
RW (kg)		Kg	KW	N	N	N/(km/h)^2
Exceeding	Upto					
----	480	455	3.8	171	3.8	0.0261
480	540	510	4.1	185	4.2	0.0282
540	595	570	4.3	194	4.4	0.0296
595	650	625	4.5	203	4.6	0.0309
650	710	680	4.7	212	4.8	0.0323
710	765	740	4.9	221	5.0	0.0337
765	850	800	5.1	230	5.2	0.0351
850	965	910	5.6	252	5.7	0.0385
965	1080	1020	6.0	270	6.1	0.0412
1080	1190	1130	6.3	284	6.4	0.0433
1190	1305	1250	6.7	302	6.8	0.0460
1305	1420	1360	7.0	315	7.1	0.0481
1420	1530	1470	7.3	329	7.4	0.0502
1530	1640	1590	7.5	338	7.6	0.0515
1640	1760	1700	7.8	351	7.9	0.0536
1760	1870	1810	8.1	365	8.2	0.0557
1870	1980	1930	8.4	378	8.5	0.0577
1980	2100	2040	8.6	387	8.7	0.0591
2100	2210	2150	8.8	396	8.9	0.0605
2210	2380	2270	9.0	405	9.1	0.0619
2380	2610	2270	9.4	423	9.5	0.0646
2610	----	2270	9.8	441	9.9	0.0674

6.1.3 The method used and the values obtained (equivalent inertia – characteristic adjustment parameter) shall be recorded in the test report.

6.2 **Preliminary Testing Cycles**

Preliminary testing cycles should be carried out if necessary to determine how best to actuate the accelerator and brake controls so as to achieve a cycle approximating to the theoretical cycle within the prescribed limits under which the cycle is carried out.

6.3 **Tyre Pressures**

The tyre pressures shall be the same as that specified by the manufacturer and used for the preliminary road test for brake adjustment. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting in the case of a two-roller dynamometer. The actual pressure used shall be recorded in the test report.

6.4 **Background Particulate Mass Measurement**

The particulate background level of the dilution air may be determined by passing filtered dilution air through the particulate filter. This shall be drawn from the same point as the particulate sample. One measurement may be performed prior to or after the test. Particulate mass measurements may be corrected by subtracting the background contribution from the dilution system. The permissible background contribution shall be ≤ 1 mg/km (or equivalent mass on the filter). If the background exceeds this level, the default figure of 1 mg/km (or equivalent mass on the filter) shall be employed. Where subtraction of the background contribution gives a negative result, the particulate mass result shall be considered to be zero.

6.5 **Background Particle Number Measurements**

The subtraction of background particle numbers may be determined by sampling dilution air drawn from a point downstream of the particle and hydrocarbon filters into the particle number measurement system. Background correction of particle number measurements shall not be allowed for type approval, but may be used at the manufacturer's request for conformity of production and in service conformity where there are indications that tunnel contribution is significant.

6.6 **Particulate Mass Filter Selection**

A single particulate filter without back-up shall be employed for both urban and extra urban phases of the cycle combined.

Twin particulate filters, one for the urban, one for the extra-urban phase, may be used without back-up filters, only where the pressure-drop increase across the sample filter between the beginning and the end of the emissions test is otherwise expected to exceed 25 kPa.

6.7 **Particulate Mass Filter Preparation**

6.7.1 Particulate mass sampling filters shall be conditioned (as regards temperature and humidity) in an open dish that has been protected against dust ingress for at least 2 and for not more than 80 hours before the test in an air-conditioned chamber. After this conditioning, the uncontaminated filters will be weighed and stored until they are used. If the filters are not used within one hour of their removal from the weighing chamber they shall be re-weighed.

6.7.2 The one hour limit may be replaced by an 8 hour limit if one or both of the following conditions are met:

6.7.2.1 A stabilized filter is placed and kept in a sealed filter holder assembly with the ends plugged; or

6.7.2.2 A stabilized filter is placed in a sealed filter holder assembly which is then immediately placed in a sample line through which there is no flow.

6.7.3 The particulate sampling system shall be started and prepared for sampling.

6.8 **Particle Number Measurement Preparation**

6.8.1 The particle specific dilution system and measurement equipment shall be started and readied for sampling.

6.8.2 Prior to the test(s) the correct function of the particle counter and volatile particle remover elements of the particle sampling system shall be confirmed according to clause 2.3.1 and 2.3.3 of Appendix 2 of Chapter 8 of this Part.

The particle counter response shall be tested at near zero prior to each test and, on a daily basis, at high particle concentrations using ambient air.

When the inlet is equipped with a High Efficiency Particulate Air (HEPA) filter, it shall be demonstrated that the entire particle sampling system is free from any leaks.

6.9 **Checking the Gas Analyzers**

The emissions analyzers for the gases shall be set at zero and spanned. The sample bags shall be evacuated.

6.10 Conditioning Procedure

6.10.1. For the purpose of measuring particulates, at most 36 hours and at least 6 hours before testing, the Part Two cycle described in this Chapter shall be used for vehicle pre- conditioning. Three consecutive cycles shall be driven. The dynamometer setting shall be indicated as in clause 6.1 of this Chapter

At the request of the manufacturer, vehicles fitted with indirect injection positive-ignition engines may be preconditioned with one Part One and two Part Two driving cycles.

6.10.2 In a test facility in which there may be possible contamination of a low particulate emitting vehicle test with residue from a previous test on a high particulate emitting vehicle, it is recommended, for the purpose of sampling equipment pre- conditioning, that a 120 km/h steady state drive cycle of 20 minutes duration followed by three consecutive Part Two cycles be driven by a low particulate emitting vehicle.

After this preconditioning, and before testing, vehicles shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20°C and 30°C).

This conditioning shall be carried out for at least 6 hours and continue until the engine oil temperature and coolant, if any, are within ±2 K of the temperature of the room.

If the manufacturer so requests, the test shall be carried out not later than 30 hours after the vehicle has been run at its normal temperature.

6.10.3 For positive-ignition engine vehicles fuelled with LPG or NG/biomethane or so equipped that they can be fuelled with either gasoline or LPG or NG/biomethane, between the tests on the first gaseous reference fuel and the second gaseous reference fuel, the vehicle shall be preconditioned before the test on the second reference fuel. This preconditioning is done on the second reference fuel by driving a preconditioning cycle consisting of one Part One (urban part) and two times Part Two (extra-urban part) of the test cycle. On the manufacturer's request and with the agreement of the Test Agency this preconditioning may be extended. The dynamometer setting shall be the one indicated in clause 6.1 of this Chapter.

6.11 Test Procedure

6.11.1 **Starting-up the engine**

6.11.1.1 The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles.

6.11.1.2 The first cycle starts on the initiation of the engine start-up procedure

6.11.1.3 In cases where LPG or NG/biomethane is used as a fuel it is permissible that the engine is started on gasoline and switched to LPG or NG/biomethane after a predetermined period of time which cannot be changed by the driver. This period of time shall not exceed 60 seconds

6.11.2 **Idling**

6.11.2.1 Manual-shift or semi-automatic gearbox, see Tables 1 and 2 of this Chapter.

6.11.2.2 Automatic- Shift Gearbox
After initial engagement the selector shall not be operated at any time during the test except in the case specified in paragraph clause 6.11.3.3 of this Chapter or if the selector can actuate the overdrive, if any.

6.11.3. **Accelerations**

6.11.3.1 Accelerations shall be so performed that the rate of acceleration is as constant as possible throughout the operation

6.11.3.2 If an acceleration cannot be carried out in the prescribed time, the extra time required shall be deducted from the time allowed for changing gear, if possible, but otherwise from the subsequent steady-speed period

6.11.3.3 Automatic-Shift Gearboxes
If acceleration cannot be carried out in the prescribed time, the gear selector shall operate in accordance with requirements for manual-shift gearboxes.

6.11.4. **Decelerations**

6.11.4.1 All decelerations of the elementary urban cycle (Part One) shall be effected by removing the foot completely from the accelerator with the clutch remaining engaged. The clutch shall be disengaged, without use of the gear lever, at the higher of the following speeds: 10 km/h or the speed corresponding to the engine idle speed.

All decelerations of the extra-urban cycle (Part Two) shall be effected by removing the foot completely from the accelerator, the clutch remaining engaged. The clutch shall be disengaged, without use of the gear lever, at a speed of 50 km/h for the last deceleration.

6.11.4.2 If the period of deceleration is longer than that prescribed for the corresponding phase, the vehicle's brakes shall be used to enable compliance with the timing of the cycle.

6.11.4.3 If the period of deceleration is shorter than that prescribed for the corresponding phase, the timing of the theoretical cycle shall be restored by constant speed or an idling period merging into the following operation.

6.11.4.4 At the end of the deceleration period (halt of the vehicle on the rollers) of the elementary urban cycle (Part One), the gears shall be placed in neutral and the clutch engaged.

6.11.5. **Steady Speeds**

"**Pumping**" or the closing of the throttle shall be avoided when passing from acceleration to the following steady speed.

Periods of constant speed shall be achieved by keeping the accelerator position fixed.

6.11.6 **Sampling**

Sampling shall begin (BS) before or at the initiation of the engine start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

6.11.7. During the test the speed is recorded against time or collected by the data acquisition system so that the correctness of the cycles performed can be assessed.

6.11.8. Particles shall be measured continuously in the particle sampling system. The average concentrations shall be determined by integrating the analyzer signals over the test cycle.

6.12. Post-Test Procedures

6.12.1 **Gas Analyzer Check**

Zero and span gas reading of the analyzers used for continuous measurement shall be checked. The test shall be considered acceptable if the difference between the pre-test and post-test results is less than 2 percent of the span gas value.

6.12.2. **Particulate Filter Weighing**

Reference filters shall be weighed within 8 hours of the test filter weighing. The contaminated particulate test filter shall be taken to the weighing chamber within one hour following the analyses of the exhaust gases. The test filter shall be conditioned for at least 2 hours and not more than 80 hours and then weighed.

6.12.3. **Bag Analysis**

The exhaust gases contained in the bag shall be analyzed as soon as possible and in any event not later than 20 minutes after the end of the test cycle.

Prior to each sample analysis, the analyzer range to be used for each pollutant shall be set to zero with the appropriate zero gas.

The analyzers shall then be set to the calibration curves by means of span gases of nominal concentrations of 70 to 100 per cent of the range.

The analyzers zero settings shall then be rechecked: if any reading differs by more than 2% of the range from that set above in this clause, the procedure shall be repeated for that analyzer.

The samples shall then be analysed.

After the analysis, zero and span points shall be rechecked using the same gases. If these rechecks are within ±2 per cent of those above in this clause, the analysis shall be considered acceptable.

At all points in this clause, the flow-rates and pressures of the various gases shall be the same as those used during calibration of the analyzers.

The figure adopted for the content of the gases in each of the pollutants measured shall be that read off after stabilization of the measuring device. Hydrocarbon mass emissions of compression-ignition engines shall be calculated from the integrated Heated Flame Ionisation Detector (HFID) reading, corrected for varying flow if necessary, as shown in clause 6.13.5 of this Chapter.

6.13 Calculation of Emissions

6.13.1 Determination of Volume

Calculation of the volume when a variable dilution device with constant flow control by orifice or venturi is used. Record continuously the parameters showing the volumetric flow, and calculate the total volume for the duration of the test.

Calculation of volume when a positive displacement pump is used

The volume of diluted exhaust gas measured in systems comprising a positive displacement pump is calculated with the following formula:

$$V = V_O \times N$$

Where:

V = Volume of the diluted gas expressed in litres per test (prior to correction),

V_O= Volume of gas delivered by the positive displacement pump in testing conditions in litres per revolution,

N = Number of revolutions per test.

Correction of Volume to Standard Conditions

The diluted exhaust-gas volume is corrected by means of the

$$V_{mix} = V \times K_1 \times \left(\frac{P_B - P_I}{T_P}\right)$$

Where:

$$K_1 = \frac{293\ (K)}{101.3\ (kPa)} = 2.8924$$

P_B = barometric pressure in the test room in kPa,

P_I = vacuum at the inlet to the positive displacement pump in kPa relative to the ambient barometric pressure,

T_P = average temperature of the diluted exhaust gas entering the positive displacement pump during the test (K).

6.13.2. Total Mass of Gaseous and Particulate Pollutants Emitted

The mass M of each pollutant emitted by the vehicle during the test shall be determined by obtaining the product of the volumetric concentration and the volume of the gas in question, with due regard for the following densities under above-mentioned reference conditions:

In the case of carbon monoxide (CO)	d = 1.164 kg/m^3
In the case of hydrocarbons:	
For gasoline (E5) ($C_1H_{1.89}O_{0.016}$)	d = 0.588 kg/m^3
For gasoline (E10) ($C_1H_{1.93}O_{0.033}$)	d = 0.601 kg/m^3
For diesel (B5) ($C_1H_{1.86}O_{0.005}$)	d = 0.580 kg/m^3
For diesel (B7) ($C_1H_{1.86}O_{0.007}$)	d = 0.581 kg/m^3
For LPG ($C_1H_{2.525}$)	d = 0.605 kg/m^3
For NG/biomethane (C_1H_4)	d = 0.665 kg/m^3
For ethanol (E85) ($C_1H_{2.74}O_{0.385}$)	d = 0.869 kg/m^3
In the case of Nitrogen Oxides (NO_x)	d = 1.913 kg/m^3
In the case of Carbon Dioxide (CO_2)	d = 1.830 kg/m^3

Mass emissions of gaseous pollutants shall be calculated by means of the following formula:

$$M_i = \frac{V_{mix} \times Q_i \times k_h \times C_i \times 10^{-6}}{d}$$

M_i = mass emission of the pollutant i in grams per kilometer,

V_{mix} = volume of the diluted exhaust gas expressed in liters per test and corrected to standard conditions (293.2 K and 101.3 kPa),

Q_i = density of the pollutant i in grams per liter at normal temperature and pressure (293.2 K and 101.3 kPa),

k_h = humidity correction factor used for the calculation of the mass emissions of oxides of nitrogen. There is no humidity correction for HC and CO,

C_i = Concentration of the pollutant i in the diluted exhaust gas expressed in ppm and corrected by the amount of the pollutant i contained in the dilution air,

d = distance corresponding to the operating cycle in kilometers.

6.13.3. Correction for Dilution Air Concentration

The concentration of pollutant in the diluted exhaust gas shall be corrected by the amount of the pollutant in the dilution air as follows:

$$C_i = C_e - C_d \times \left(1 - \frac{1}{DF}\right)$$

Where:

C_i = concentration of the pollutant i in the diluted exhaust gas, expressed in ppm and corrected by the amount of i contained in the dilution air,

C_e = measured concentration of pollutant i in the diluted exhaust gas, expressed in ppm,

Cd = concentration of pollutant i in the air used for dilution, expressed in ppm,

DF = dilution factor.

The dilution factor is calculated as follows: For each reference fuel, except hydrogen

$$DF = \frac{X}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$

For a fuel of composition CxHyOz, the general formula is:

$$X = 100 \frac{x}{x + \frac{y}{2} + 3.76 * \left(x + \frac{y}{4} - \frac{z}{2}\right)}$$

The dilution factors for the reference fuels covered by this Part are provided below:

$$DF = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$ for gasoline (E5)

$$DF = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$ for gasoline (E10)

$$DF = \frac{13.5}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$ for diesel (B5)

$$DF = \frac{13.5}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$ for diesel (B7)

$$DF = \frac{11.9}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$ for LPG

$$DF = \frac{9.5}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}} \quad \text{for NG/biomethane}$$

$$DF = \frac{12.5}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}} \quad \text{for Ethanol (E85)}$$

$$DF = \frac{12.3}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}} \quad \text{for Ethanol (E100)}$$

$$DF = \frac{35.03}{C_{H_2O} - C_{H_2O-DA} + C_{H_2} * 10^{-4}} \quad \text{for Hydrogen}$$

In these equations:

C_{CO2} = concentration of CO_2 in the diluted exhaust gas contained in the sampling bag, expressed in percent volume,

C_{HC} = concentration of HC in the diluted exhaust gas contained in the sampling bag, expressed in ppm carbon equivalent,

C_{CO} = concentration of CO in the diluted exhaust gas contained in the sampling bag, expressed in ppm,

C_{H2O} = concentration of H_2O in the diluted exhaust gas contained in the sampling bag, expressed in percent volume,

C_{H2O-DA} = concentration of H_2O in the air used for dilution, expressed in per cent volume,

C_{H2} = concentration of hydrogen in the diluted exhaust gas contained in the sampling bag, expressed in ppm

Non-methane hydrocarbon concentration is calculated as follows:

C_{NMHC} = $C_{THC} - (Rf_{CH4} \cdot C_{CH4})$

Where:

C_{NMHC} = corrected concentration of NMHC in the diluted exhaust gas, expressed in ppm carbon equivalent,

C_{THC} = concentration of THC in the diluted exhaust gas, expressed in ppm carbon equivalent and corrected by the amount of THC contained in the dilution air

C_{CH4} = concentration of CH4 in the diluted exhaust gas, expressed in ppm carbon equivalent and corrected by the amount of CH_4 contained in the dilution air,

Rf_{CH4} = is the FID response factor to methane as defined in clause 2.3.3 of Chapter 7 to this Part.

6.13.4. Calculation of the NO Humidity Correction Factor

In order to correct the influence of humidity on the results of oxides of nitrogen, the following calculations are applied:

$$K_h = \frac{1}{1 - 0.0329 * (H - 10.71)}$$

In which:

$$H = \frac{6.211 * R_a * P_d}{P_B - P_d * R_a * 10^{-2}}$$

Where:

H = absolute humidity expressed in grams of water per kilogram of dry air,

Ra = relative humidity of the ambient air expressed as a percentage,

P_d = saturation vapour pressure at ambient temperature expressed in kPa,

P_B = atmospheric pressure in the room, expressed in kPa.

6.13.5. Determination of HC for Compression-ignition Engines

To calculate HC-mass emission for compression-ignition engines, the average HC concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{HC} * dt}{t_2 - t_1}$$

Where:

$\int_{t_1}^{t_2} C_{HC} * dt$	=	integral of the recording of the heated FID over the test (t_2-t_l)
Ce	=	concentration of HC measured in the diluted exhaust in ppm of C_i is substituted for C_{HC} in all relevant equations.

6.13.6 Determination of Particulates

Particulate emission Mp (g/km) is calculated by means of the following equation:

$$M_p = \frac{(V_{mix} + V_{ep}) \cdot P_e}{V_{ep} \cdot d}$$

Where exhaust gases are vented outside tunnel;

$$M_p = \frac{V_{mix} \cdot P_e}{V_{ep} \cdot d}$$

Where exhaust gases are returned to the tunnel;

Where:

V_{mix} = volume of diluted exhaust gases (see clause 6.13.1 of this Chapter.), under standard conditions,
V_{ep} = volume of exhaust gas flowing through particulate filter under standard conditions,
P_e = particulate mass collected by filter(s),
D = distance corresponding to the operating cycle in km,
M_p = particulate emission in g/km.

Where correction for the particulate background level from the dilution system has been used, this shall be determined in accordance with clause 6.4 of this Chapter. In this case, the particulate mass (g/km) shall be calculated as follows:

$$M_p = \left[\frac{P_e}{V_{ep}} - \left(\frac{P_a}{V_{ap}} \cdot \left(1 - \frac{1}{DF}\right)\right)\right] \cdot \frac{(V_{mix} + V_{ep})}{d}$$

Where exhaust gases are vented outside tunnel;

$$M_p = \left[\frac{P_e}{V_{ep}} - \left(\frac{P_a}{V_{ap}} \cdot \left(1 - \frac{1}{DF} \right) \right) \right] \cdot \frac{V_{mix}}{d}$$

Where exhaust gases are returned to the tunnel.

Where:

V_{ap} = volume of tunnel air flowing through the background particulate filter under standard conditions,

Pa = particulate mass collected by background filter,

DF = dilution factor as determined in clause 6.13.3 of this Chapter.

Where application of a background correction results in a negative particulate mass (in g/km) the result shall be considered to be zero g/km particulate mass.

6.13.7 Determination of Particle Numbers

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

$$N = \frac{V.k.\overline{C_s}.\overline{f_r}.10^3}{d}$$

Where:

N = particle number emission expressed in particulates per kilometer,

V = volume of the diluted exhaust gas expressed in litres per test and corrected to standard conditions (293 K and 101.33 kPa),

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

$\overline{C_s}$ = corrected concentration of particulates from the diluted exhaust gas expressed as the average particulates per cubic centimeter figure from the emissions test including the full duration of the drive cycle. If the volumetric mean concentration results ($\overline{C}$) from the particle number counter are not output at standard conditions (293 K and 101.33 kPa), then the concentrations should be corrected to those conditions ($\overline{C_s}$)

$\overline{f_r}$ = mean particulate concentration reduction factor of the volatile particulate remover at the dilution setting used for the test,

d = distance corresponding to the operating cycle expressed in kilometers,

$\overline{C}$ = shall be calculated from the following equation:

$$\overline{C} = \frac{\sum_{i=1}^{i=n} C_i}{n}$$

Where:

C_i = a discrete measurement of particle concentration in the diluted gas exhaust from the particulate counter expressed in particulate per cubic centimeter and corrected for coincidence,

n = Total number of discrete particulate concentration measurements made during the operating cycle, shall be calculated from the following equation:

$$n = T \cdot f$$

Where:

T = time duration of the operating cycle expressed in seconds,

f = data logging frequency of the particle counter expressed in Hz

6.13.9 Allowance for Mass Emissions from Vehicles Equipped with Periodically Regenerating Devices

When the vehicle is equipped with a periodically regenerating system as defined in Chapter 15 of this Part.

6.13.9.1. The provisions of Chapter 15 shall apply for the purposes of particulate mass measurements only and not particle number measurements.

6.13.9.2. For particulate mass sampling during a test in which the vehicle undergoes a scheduled regeneration, the filter face temperature shall not exceed 192 °C.

6.13.9.3. For particulate mass sampling during a test when the regenerating device is in a stabilized loading condition (i.e. the vehicle is not undergoing a regeneration), it is recommended that the vehicle has completed > 1/3 of the mileage between scheduled regenerations or that the periodically regenerating device has undergone equivalent loading off the vehicle.

6.13.9.3.1. For the purposes of conformity of production testing, the manufacturer may ensure that this is included within the evolution coefficient. In this case if the manufacturer wishes to run in the vehicles, ("x" km, where x ≤ 3,000 km for vehicles equipped with a positive ignition engine and x ≤ 15,000 km for vehicles equipped with a compression ignition engine and where the vehicle is at > 1/3 distance between successive regenerations), the procedure will be as follows:

(a) The pollutant emissions (type I) will be measured at zero and at "x" km on the first tested vehicle;

(b) The evolution coefficient of the emissions between zero and "x" km will be calculated for each of the pollutants:

$$\text{Evolution coefficient} = \frac{\text{Emission at “x” km}}{\text{Emission at zero km}}$$

This may be less than 1,

The other vehicles will not be run in, but their zero km emissions will be multiplied by the evolution coefficient.

In this case, the values to be taken will be:

(a) The values at "x" km for the first vehicle;

(b) The values at zero km multiplied by the evolution coefficient for the other vehicles

7.0 CALCULATION OF FUEL CONSUMPTION

The fuel consumption, expressed in litres per 100 km (in the case of gasoline (E5/E10), LPG, ethanol (E85/E100) and diesel (B5/B7)), in m^3 per 100 km (in the case of NG/biomethane and H2NG) or in kg per 100km (in the case of hydrogen) is calculated by means of the following formulae:

(a) For vehicles with a positive ignition engine fuelled with gasoline (E5):

$$FC = (0.118/D) \times [(0.848 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)];$$

(b) For vehicles with a positive ignition engine fuelled with gasoline (E10):

$$FC = (0.120/D) \times [(0.830 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

(c) For vehicles with a positive ignition engine fuelled with LPG:

$$FCnorm = (0.1212/0.538) \times [(0.825 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

If the composition of the fuel used for the test differs from the composition that is assumed for the calculation of the normalised consumption, on the manufacturer's request a correction factor cf may be applied, as follows:

$$FCnorm = (0.1212/0.538) \times (cf) \times [(0.825 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

The correction factor cf, which may be applied, is determined as follows:

$$cf = 0.825 + 0.0693 \times n_{actual}$$

Where:

n_{actual} = the actual H/C ratio of the fuel used;

(d) For vehicles with a positive ignition engine fuelled with NG/biomethane:

$$FCnorm = (0.1336/0.654) \times [(0.749 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

(e) For vehicles with a compression ignition engine fuelled with diesel (B5):

$$FC = (0.116/D) \times [(0.861 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

(f) For vehicles with a compression ignition engine fuelled with diesel (B7):

$$FC = (0.116/D) \times [(0.859 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

(g) For vehicles with a positive ignition engine fuelled with ethanol (E85):

$$FC = (0.1742/D) \times [(0.574 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]$$

(h) For vehicles with a positive ignition engine fuelled by H2NG:

$$FC = \left(\frac{910.4 * A + 13.600}{44.655 * A^2 + 667.08 * A}\right) * \left(\frac{7.848 * A}{9.104 * A + 136} * HC + 0.429 * CO + 0.273 * CO_2\right)$$

(i) For vehicles fuelled by gaseous hydrogen

$$FC = 0.024 \frac{V}{d}\left[\frac{1}{Z_1}\frac{p_1}{T_1} - \frac{1}{Z_2}\frac{p_2}{T_2}\right]$$

Under previous agreement with the Test Agency, and for vehicles fuelled either by gaseous or liquid hydrogen, the manufacturer may choose as alternative to the method above, either the formula

$$FC = 0.1 \times (0.1119 \times H_2O + H_2)$$

For vehicles powered by internal combustion engine only, or a method according to standard protocols such as SAE J2572 or ISO 23828.

In these formulae:

FC = the fuel consumption in litre per 100km (in the case of gasoline (E5/E10), ethanol, LPG, diesel (B5/B7) or biodiesel) or in m3 per 100km (in the case of natural gas and H2NG) or in kg per 100km in the case of hydrogen.

HC = the measured emission of hydrocarbons in g/km;

CO = the measured emission of carbon monoxide in g/km;

CO_2 = the measured emission of carbon dioxide in g/km;

H_2O = The measured emission of H_2O in g/km

H_2 = The measured emission of H_2 in g/km

A = Quantity of NG/biomethane within the H2NG mixture, expressed in per cent Volume

D = the density of the test fuel. In the case of gaseous fuels this is the density at 15°C

d = The theoretical distance covered by a vehicle tested under the Type I test in km.

p_1 = Pressure in gaseous fuel tank before the operating cycle in Pa;

p_2 = Pressure in gaseous fuel tank after the operating cycle in Pa;

T_1 = Temperature in gaseous fuel tank before the operating cycle in K.

T_2 = Temperature in gaseous fuel tank after the operating cycle in K.

Z_1 = Compressibility factor of the gaseous fuel at p_1 and T_1

Z_2 = compressibility factor of the gaseous fuel at p_2 and T_2

V = Inner volume of the gaseous fuel tank in m^3

The compressibility factor shall be obtained from the following Table 1A of this Chapter:

Table 1 A

	T (K)	5	100	200	300	400	500	600	700	800	900
p(bar)	33	0.859	1.051	1.885	2.648	3.365	4.051	4.712	5.352	5.973	6.576
	53	0.965	0.922	1.416	1.891	2.338	2.765	3.174	3.57	3.954	4.329
	73	0.989	0.991	1.278	1.604	1.923	2.229	2.525	2.81	3.088	3.358
	93	0.997	1.042	1.233	1.47	1.711	1.947	2.177	2.4	2.617	2.829
	113	1	1.066	1.213	1.395	1.586	1.776	1.963	2.146	2.324	2.498
	133	1.002	1.076	1.199	1.347	1.504	1.662	1.819	1.973	2.124	2.271
	153	1.003	1.079	1.187	1.312	1.445	1.58	1.715	1.848	1.979	2.107
	173	1.003	1.079	1.176	1.285	1.401	1.518	1.636	1.753	1.868	1.981
	193	1.003	1.077	1.165	1.263	1.365	1.469	1.574	1.678	1.781	1.882
	213	1.003	1.071	1.147	1.228	1.311	1.396	1.482	1.567	1.652	1.735
	233	1.004	1.071	1.148	1.228	1.312	1.397	1.482	1.568	1.652	1.736
	248	1.003	1.069	1.141	1.217	1.296	1.375	1.455	1.535	1.614	1.693
	263	1.003	1.066	1.136	1.207	1.281	1.356	1.431	1.506	1.581	1.655
	278	1.003	1.064	1.13	1.198	1.268	1.339	1.409	1.48	1.551	1.621
	293	1.003	1.062	1.125	1.19	1.256	1.323	1.39	1.457	1.524	1.59
	308	1.003	1.06	1.12	1.182	1.245	1.308	1.372	1.436	1.499	1.562
	323	1.003	1.057	1.116	1.175	1.235	1.295	1.356	1.417	1.477	1.537
	338	1.003	1.055	1.111	1.168	1.225	1.283	1.341	1.399	1.457	1.514
	353	1.003	1.054	1.107	1.162	1.217	1.272	1.327	1.383	1.438	1.493

In the case that the needed input values for p and T are not indicated in the Table, the compressibility factor shall be obtained by linear interpolation between the compressibility factors indicated in the Table, choosing the ones that are the closest to the sought value.

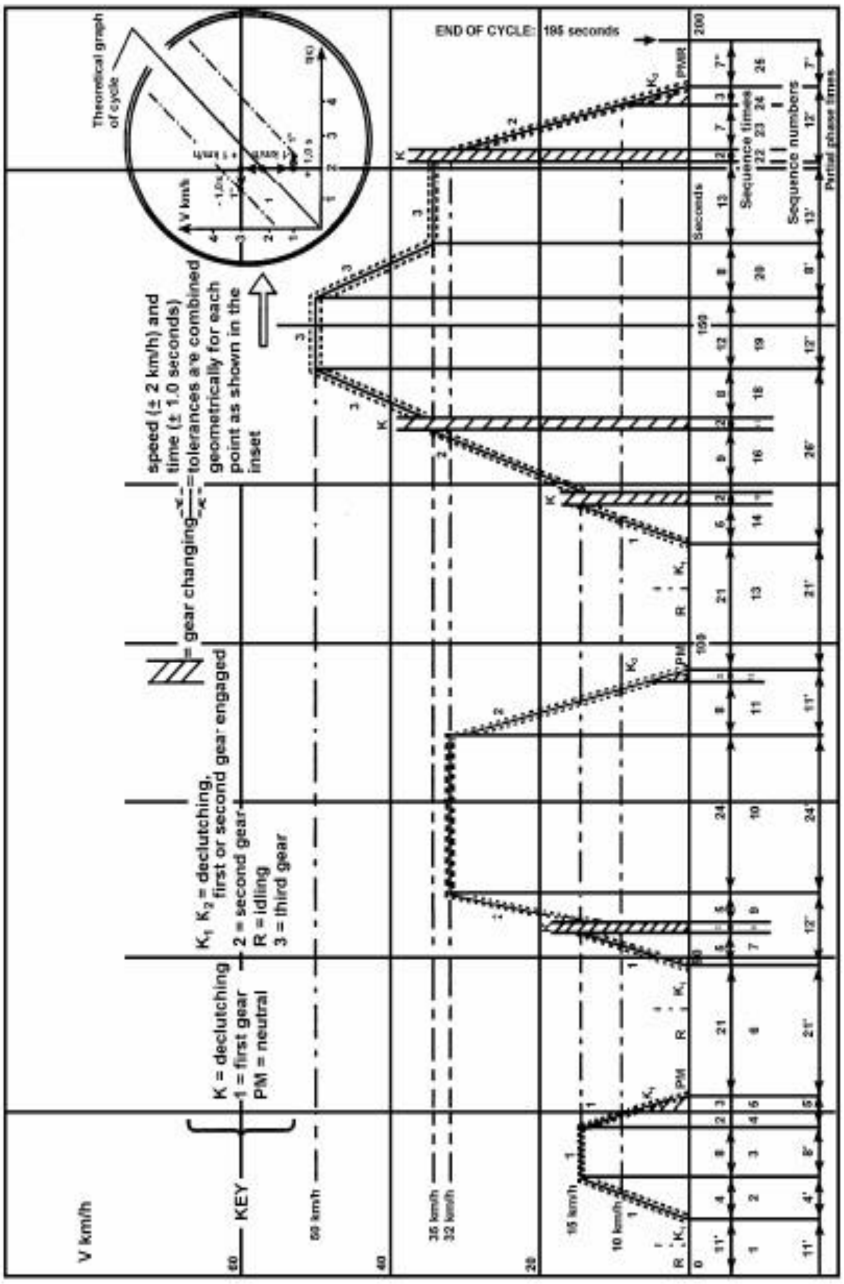


Figure 1
Elementary Urban Cycle for the Type I Test

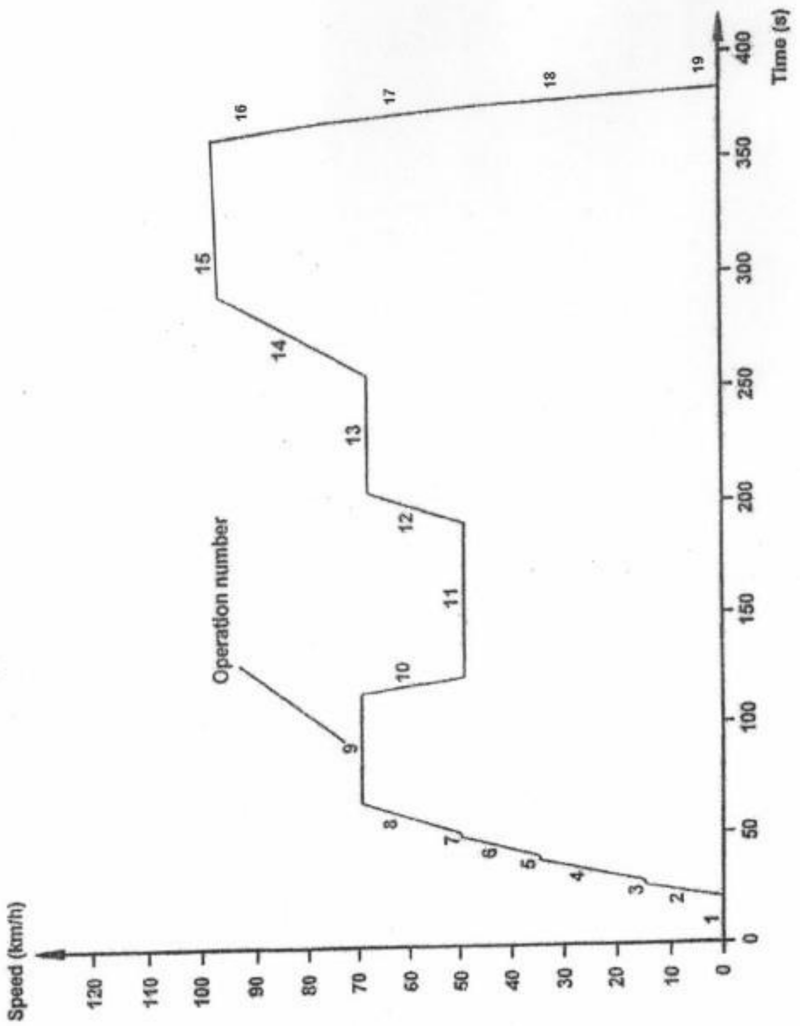


Figure 2
Extra – Urban Cycle (Part Two) for Type I Test

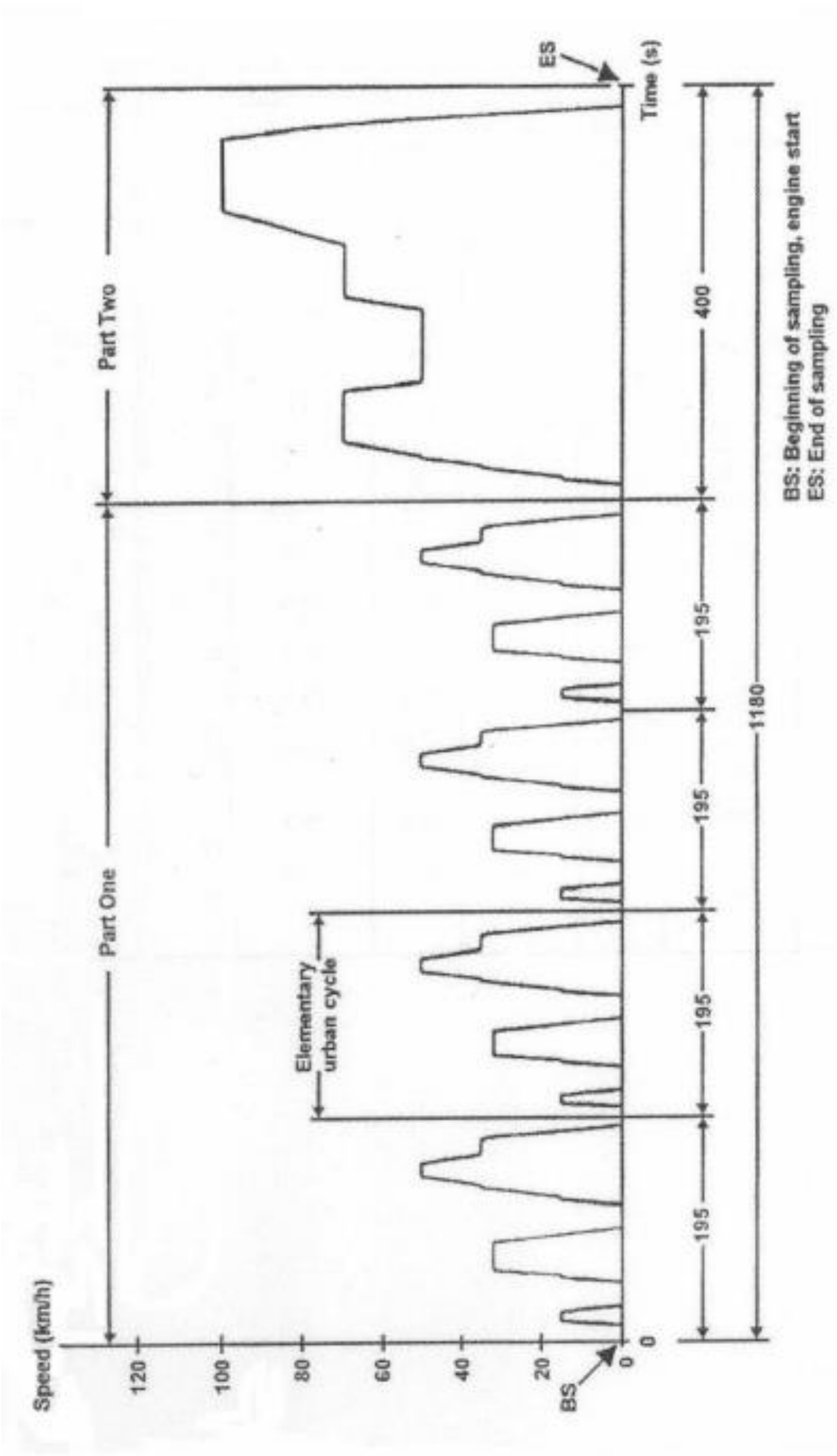


Figure 3
Operating Cycle for the Type I Test

Table 2
Modified Indian Driving Cycle (MIDC) Elementary Urban (Part One) for the Type I Test

	Operation	Phase	Acceleration (m/s^2)	Speed (km/h)	Duration of each: Operation (s)	Duration of each: Phase (s)	Cumulative time (s)	Gear to be used in the case of a manual gearbox
1	Idling	1	0	0	11	11	11	6 s PM + 5 s K_1 [1]
2	Acceleration	2	1.04	0-15	4	4	15	1
3	Steady speed	3	0	15	9	8	23	1
4	Deceleration	4	-0.69	15-10	2	5	25	1
5 5	Deceleration, clutch disengaged		-0.92	10-0	3		28	K_1 [1]
6	Idling	5	0	0	21	21	49	16 s PM + 5 s K_1 [1]
7	Acceleration	6	0.83	0-15	5	12	54	1
8	Gear change			15	2		56	
9	Acceleration		0.94	15-32	5		61	2
10	Steady speed	7	0	32	24	24	85	2
11	Deceleration	8	-0.75	32-10	8	11	93	2
12	Deceleration, clutch disengaged		-0.92	10-0	3		96	K_2 [1]
13	Idling	9	0	0	21		117	16 s PM + 5 s K_1 [1]
14	Acceleration	10	0.83	0-15	5	26	122	1
15	Gear change			15	2		124	
16	Acceleration		0.62	15-35	9		133	2
17	Gear change			35	2		135	
18	Acceleration		0.52	35-50	8		143	3
19	Steady speed	11	0	50	12	12	155	3
20	Deceleration	12	-0.52	50-35	8	8	163	3
21	Steady speed	13	0	35	13	13	176	3
22	Gear change	14		35	2	12	178	
23	Deceleration		-0.99	35-10	7		185	2
24	Deceleration clutch disengaged		-0.92	10-0	3		188	K_2 [1]
25	Idling	15	0	0	7	7	195	7 s PM [1]

[1] PM = gearbox in neutral, clutch engaged. K_1, K_2 = first or second gear engaged, clutch disengaged.

Table 2A
Breakdown of Part One of Modified Indian Driving Cycle (MIDC)

Elementary urban cycle

Breakdown by phases:

	Time (s)	per cent	
Idling	60	30.8	35.4
Deceleration, clutch disengaged	9	4.6	
Gear-changing	8	4.1	
Accelerations	36	18.5	
Steady-speed periods	57	29.2	
Decelerations	25	12.8	
Total	195	100	

Breakdown by use of gears:

	Time (s)	per cent	
Idling	60	30.8	35.4
Deceleration, clutch disengaged	9	4.6	
Gear-changing	8	4.1	
First gear	24	12.3	
Second gear	53	27.2	
Third gear	41	21	
Total	195	100	

General information:

Average speed during test : 19 km/h

Effective running time : 195 s

Theoretical distance covered per cycle : 1.013 km

Equivalent distance for the four cycles : 4.052 km

Table 3

Modified Indian Driving Cycle (MIDC) Extra-urban (Part Two) for the Type I Test

No. of Opera-tion	Operation	Phase	Acceleration (m/s²)	Speed (km/h)	Duration of each Operation(s)	Duration of each Phase(s)	Cumulative Time(s)	Gear to be used in the case of a manual gearbox
1	Idling	1	0	0	20	20	20	K_1[1]
2	Acceleration	2	0.83	0-15	5	41	25	1
3	Gear change			15	2		27	-
4	Acceleration		0.62	15-35	9		36	2
5	Gear change			35	2		38	-
6	Acceleration		0.52	35-50	8		46	3
7	Gear change			50	2		48	-
8	Acceleration		0.43	50-70	13		61	4
9	Steady speed	3	0	70	50	50	111	5
10	Deceleration	4	-0.69	70-50	8	8	119	4s 5+ 4s 4
11	Steady speed	5	0	50	69	69	188	4
12	Acceleration	6	0.43	50-70	13	13	201	4
13	Steady speed	7	0	70	50	50	251	5
14	Acceleration	8	0.24	70-90	24	24	275	5
15	Steady speed[2]	9	0	90	83	83	358	5[2]
16	Deceleration[2]	10	-0.69	90-80	4	22	362	5[2]
17	Deceleration[2]		-1.04	80-50	8		370	5[2]
18	Deceleration, clutch, disengaged		1.39	50-0	10		380	K_5[1]
19	Idle	11	0	0	20	20	400	PM[1]

[1] PM = gear box in neutral, clutch engaged. K_1, K_5 = first or second gear engaged, clutch disengaged

[2] Additional gears can be used according to manufacturer recommendations if the vehicle is equipped with a transmission with more than five gears.

Table 3A
Breakdown of the Part – Two of Modified Indian Driving Cycle
(EXTRA –URBAN CYCLE)

Breakdown by phases

	Time(s)	**%**
Idling	20	5.0
Idling, Vehicle moving, clutch engaged on one combination	20	5.0
Gear Changing	6	1.5
Accelerations	72	18.0
Steady-speed periods	252	63.0
Decelerations	30	7.5
	400	**100**

Breakdown by use of gears

	Time (s)	**%**
Idling	20	5.0
Idling, Vehicle moving, clutch engaged on one combination	20	5.0
Gear Changing	6	1.5
First Gear	5	1.3
Second Gear	9	2.2
Third Gear	8	2.0
Fourth Gear	99	24.8
Fifth Gear	233	58.2
	400	**100**

General Information

Average speed during test : 59.3 km/h
Effective running time : 400 seconds
Theoretical distance covered per cycle : 6.594 km
Maximum Speed : 90 km/h
Maximal Acceleration : 0.833 m/s^2
Maximal Deceleration : -1.389 m/s^2

CHAPTER 4 - APPENDIX 1
CHASSIS DYNAMOMETER SYSTEM

1.0 SPECIFICATION

1.1. General Requirements

1.1.1. The dynamometer shall be capable of simulating road load within one of the following classifications:

(a) Dynamometer with fixed load curve, i.e. a dynamometer whose physical characteristics provide a fixed load curve shape;

(b) Dynamometer with adjustable load curve, i.e. a dynamometer with at least two road load parameters that can be adjusted to shape the load curve.

1.1.2. Dynamometers with electric inertia simulation shall be demonstrated to be equivalent to mechanical inertia systems. The means by which equivalence is established are described in Appendix 1 of Chapter 5 of this Part

1.1.3. In the event that the total resistance to progress on the road cannot be reproduced on the chassis dynamometer between speeds of 10 km/h and 90 km/h, it is recommended that a chassis dynamometer having the characteristics defined below should be used.

1.1.3.1. The load absorbed by the brake and the chassis dynamometer internal frictional effects between the speeds of 0 and 90 km/h is as follows:

$F = (a + b \cdot V^2) \pm 0.1 \cdot F_{80}$ (without being negative)

Where:

F = total load absorbed by the chassis dynamometer (N),
a = value equivalent to rolling resistance (N),
b = value equivalent to coefficient of air resistance ($N/(km/h)^2$),
V = speed (km/h),
F_{80} = load at 80 km/h (N).

1.2. Specific Requirements

1.2.1 The setting of the dynamometer shall not be affected by the lapse of time. It shall not produce any vibrations perceptible to the vehicle and likely to impair the vehicle's normal operations.

1.2.2. The chassis dynamometer may have one or two rollers. The front roller shall drive, directly or indirectly, the inertial masses and the power absorption device.

1.2.3. It shall be possible to measure and read the indicated load to an accuracy of ±5 %

1.2.4. In the case of a dynamometer with a fixed load curve, the accuracy of the load setting at 80 km/h shall be ±5 %. In the case of a dynamometer with adjustable load curve, the accuracy of matching dynamometer load to road load shall be ±5 % at 90, 80, 60, and 40 km/h and ±10 % at 20 km/h. Below this, dynamometer absorption shall be positive.

1.2.5. The total inertia of the rotating parts (including the simulated inertia where applicable) shall be known and shall be within ± 20 kg of the inertia class for the test.

1.2.6. The speed of the vehicle shall be measured by the speed of rotation of the roller (the front roller in the case of a two-roller dynamometer). It shall be measured with an accuracy of ±1 km/h at speeds above 10 km/h.

The distance actually driven by the vehicle shall be measured by the movement of rotation of the roller (the front roller in the case of a two-roller dynamometer).

2.0 DYNAMOMETER CALIBRATION PROCEDURE

2.1. Introduction

This section describes the method to be used to determine the load absorbed by a dynamometer brake. The load absorbed comprises the load absorbed by frictional effects and the load absorbed by the power-absorption device.

The dynamometer is brought into operation beyond the range of test speeds. The device used for starting up the dynamometer is then disconnected: the rotational speed of the driven roller decreases.

The kinetic energy of the rollers is dissipated by the power-absorption unit and by the frictional effects. This method disregards variations in the roller's internal frictional effects caused by rollers with or without the vehicle. The frictional effects of the rear roller shall be disregarded when the roller is free.

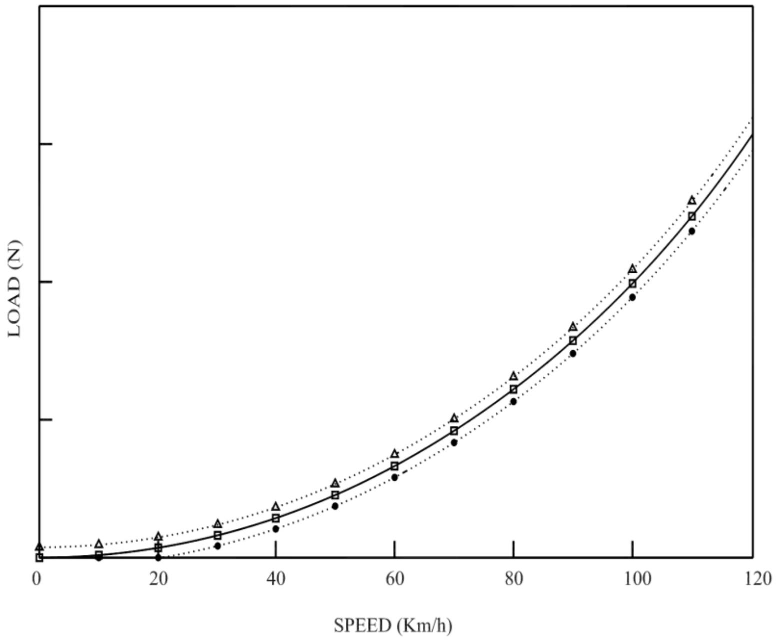
2.2. Calibration of the Load Indicator at 80 km/h

The following procedure shall be used for calibration of the load indicator to 80 km/h as a function of the load absorbed (see also Figure 1 of this Appendix):

2.2.1. Measure the rotational speed of the roller if this has not already been done. A fifth wheel, a revolution counter or some other method may be used.

2.2.2. Place the vehicle on the dynamometer or devise some other method of starting-up the dynamometer.

2.2.3. Use the flywheel or any other system of inertia simulation for the particular inertia class to be used



Legend:

$\square = F = a + b * V^2$

$\bullet = F = (a + b * V^2) - 0.1 * F_{80}$

$\Delta = F = (a + b * V^2) + 0.1 * F_{80}$

Figure 1
Diagram Illustrating the Power Absorbed by the Chassis Dynamometer

2.2.4. Bring the dynamometer to a speed of 80 km/h.

2.2.5. Note the load indicated F_i (N).

2.2.6. Bring the dynamometer to a speed of 90 km/h.

2.2.7. Disconnect the device used to start-up the dynamometer.

2.2.8. Note the time taken by the dynamometer to pass from a speed of 85 km/h to a speed of 75 km/h.

2.2.9. Set the power-absorption device at a different level.

2.2.10. The requirements of clauses 2.2.4 to 2.2.9 of this Appendix shall be repeated sufficiently often to cover the range of loads used.

2.2.11. Calculate the load absorbed using the formula:

$$F = \frac{M_i * \Delta V}{t}$$

Where:

F = load absorbed (N),

M_i = equivalent inertia in kg (excluding the inertial effects of the free rear roller),

ΔV = speed deviation in m/s (10 km/h = 2.775 m/s),

t = time taken by the roller to pass from 85 km/h to 75 km/h.

2.2.12. Figure 2 of this Appendix shows the load indicated at 80 km/h in terms of load absorbed at 80 km/h.

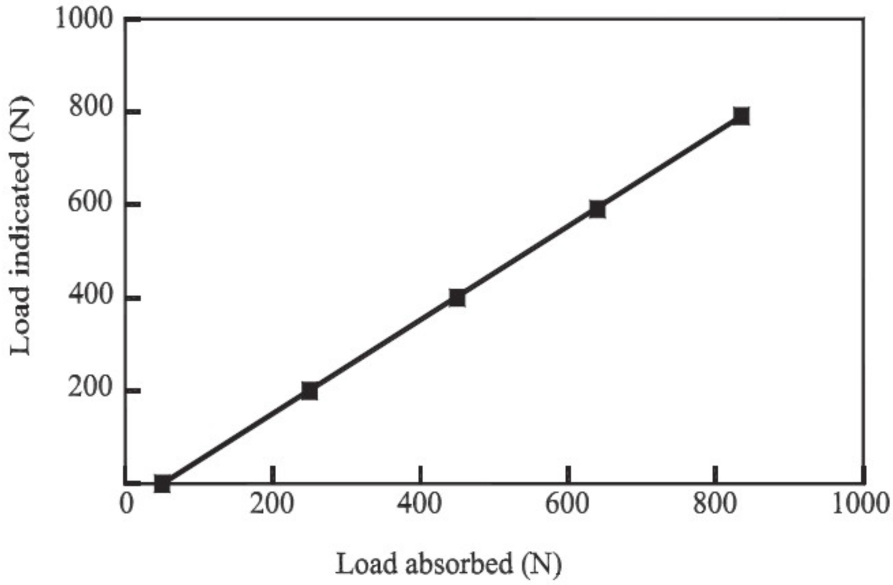


Figure 2

2.2.13. The requirements of clauses 2.2.3 to 2.2.12 above shall be repeated for all inertia classes to be used.

2.3. **Calibration of the Load Indicator at Other Speeds**

The procedures described in clause 2.2 of this Appendix shall be repeated as often as necessary for the chosen speeds.

2.4. **Calibration of Force or Torque**

The same procedure shall be used for force or torque calibration.

3.0. VERIFICATION OF THE LOAD CURVE

3.1. **Procedure**

The load-absorption curve of the dynamometer from a reference setting at a speed of 80 km/h shall be verified as follows:

3.1.1. Place the vehicle on the dynamometer or devise some other method of starting-up the dynamometer.

3.1.2. Adjust the dynamometer to the absorbed load (F) at 80 km/h.

3.1.3. Note the load absorbed at 90, 80, 60, 40 and 20 km/h.

3.1.4. Draw the curve F(V) and verify that it corresponds to the requirements of clause 1.1.3.1. of this Appendix.

3.1.5. Repeat the procedure set out in clauses 3.1.1 to 3.1.4 of this Appendix for other values of power F at 80 km/h and for other values of inertias.

CHAPTER 4 - APPENDIX 2

EXHAUST DILUTION SYSTEM

1.0 SYSTEM SPECIFICATION

1.1. System Overview

A full-flow exhaust dilution system shall be used. This requires that the vehicle exhaust be continuously diluted with ambient air under controlled conditions. The total volume of the mixture of exhaust and dilution air shall be measured and a continuously proportional sample of the volume shall be collected for analysis. The quantities of pollutants are determined from the sample concentrations, corrected for the pollutant content of the ambient air and the totalized flow over the test period.

The exhaust dilution system shall consist of a transfer tube, a mixing chamber and dilution tunnel, a dilution air conditioning, a suction device and a flow measurement device. Sampling probes shall be fitted in the dilution tunnel as specified in Chapter 7 and 8 of this Part.

The mixing chamber described above will be a vessel, such as those illustrated in Figures 1 and 2 of this Appendix, in which vehicle exhaust gases and the dilution air are combined so as to produce a homogeneous mixture at the chamber outlet.

1.2. General Requirements

1.2.1. The vehicle exhaust gases shall be diluted with a sufficient amount of ambient air to prevent any water condensation in the sampling and measuring system at all conditions which may occur during a test.

1.2.2. The mixture of air and exhaust gases shall be homogeneous at the point where the sampling probe is located (see clause 1.3.3. of this Appendix). The sampling probe shall extract a representative sample of the diluted exhaust gas.

1.2.3. The system shall enable the total volume of the diluted exhaust gases to be measured.

1.2.4. The sampling system shall be gas-tight. The design of the variable dilution sampling system and the materials that go to make it up shall be such that they do not affect the pollutant concentration in the diluted exhaust gases. Should any component in the system (heat exchanger, cyclone separator, blower, etc.) change the concentration of any of the pollutants in the diluted exhaust gases and the fault cannot be corrected, then sampling for that pollutant shall be carried out upstream from that component.

1.2.5. All parts of the dilution system that are in contact with raw and diluted exhaust gas, shall be designed to minimize deposition or alteration of the particulates or particles. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

1.2.6. If the vehicle being tested is equipped with an exhaust pipe comprising several branches, the connecting tubes shall be connected as near as possible to the vehicle without adversely affecting its operation.

1.2.7. The variable-dilution system shall be so designed as to enable the exhaust gases to be sampled without appreciably changing the back-pressure at the exhaust pipe outlet.

1.2.8. The connecting tube between the vehicle and dilution system shall be designed so as to minimize heat loss.

1.3. Specific Requirements

1.3.1. **Connection to Vehicle Exhaust**

The connecting tube between the vehicle exhaust outlets and the dilution system shall be as short as possible; and satisfy the following requirements:

(a) Be less than 3.6 m long, or less than 6.1 m long if heat insulated. Its internal diameter may not exceed 105 mm;

(b) Shall not cause the static pressure at the exhaust outlets on the vehicle being tested to; differ by more than ±0.75 kPa at 50 km/h, or more than ±1.25 kPa for the whole duration of the test from the static pressures recorded when nothing is connected to the vehicle exhaust outlets. The pressure shall be measured in the exhaust outlet or in an extension having the same diameter, as near as possible to the end of the pipe. Sampling systems capable of maintaining the static pressure to within ±0.25 kPa may be used if a written request from a manufacturer to the Test Agency substantiates the need for the closer tolerance;

(c) Shall not change the nature of the exhaust gas;

(d) Any elastomer connectors employed shall be as thermally stable as possible and have minimum exposure to the exhaust gases.

1.3.2. **Dilution Air Conditioning**

The dilution air used for the primary dilution of the exhaust in the Constant Volume Sampling (CVS) tunnel shall be passed through a medium capable of reducing particulates in the most penetrating particulate size of the filter material by ≥ 99.95 % or through a filter of at least class H13 of EN 1822:1998. This represents the specification of

High Efficiency Particulate Air (HEPA) filters. The dilution air may optionally be charcoal scrubbed before being passed to the HEPA filter. It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal scrubber, if used.

At the vehicle manufacturer's request, the dilution air may be sampled according to good engineering practice to determine the tunnel contribution to background particulate mass levels, which can then be subtracted from the values measured in the diluted exhaust.

1.3.3. **Dilution Tunnel**

Provision shall be made for the vehicle exhaust gases and the dilution air to be mixed. A mixing orifice may be used.

In order to minimize the effects on the conditions at the exhaust outlet and to limit the drop in pressure inside the dilution-air conditioning device, if any, the pressure at the mixing point shall not differ by more than ±0.25 kPa from atmospheric pressure.

The homogeneity of the mixture in any cross-section at the location of the sampling probe shall not vary by more than ±2 % from the average of the values obtained for at least five points located at equal intervals on the diameter of the gas stream.

For particulate and particle emissions sampling, a dilution tunnel shall be used which:

(a) Shall consist of a straight tube of electrically-conductive material, which shall be earthed;
(b) Shall be small enough in diameter to cause turbulent flow (Reynolds number $\geq$ 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air;
(c) Shall be at least 200 mm in diameter;
(d) May be insulated.

1.3.4. **Suction Device**

This device may have a range of fixed speeds to ensure sufficient flow to prevent any water condensation. This result is generally obtained if the flow is either:

(a) Twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle; or

(b) Sufficient to ensure that the CO_2 concentration in the dilute exhaust sample bag is less than 3 % by volume for gasoline and diesel, less than 2.2 % by volume for LPG and less than 1.5 % by volume for NG/biomethane.

1.3.5. Volume Measurement in the Primary Dilution System

The method of measuring total dilute exhaust volume incorporated in the constant volume sampler shall be such that measurement is accurate to ±2 % under all operating conditions. If the device cannot compensate for variations in the temperature of the mixture of exhaust gases and dilution air at the measuring point, a heat exchanger shall be used to maintain the temperature to within ±6 K of the specified operating temperature.

If necessary, some form of protection for the volume measuring device may be used e.g. a cyclone separator, bulk stream filter, etc.

A temperature sensor shall be installed immediately before the volume measuring device. This temperature sensor shall have an accuracy and a precision of ±1 K and a response time of 0.1 s at 62 % of a given temperature variation (value measured in silicone oil).

The measurement of the pressure difference from atmospheric pressure shall be taken upstream from and, if necessary, downstream from the volume measuring device.

The pressure measurements shall have a precision and an accuracy of ±0.4 kPa during the test.

1.4. Recommended System Descriptions

Figure 1 and 2 of this Appendix are schematic drawings of two types of recommended exhaust dilution systems that meet the requirements of this Appendix.

Since various configurations can produce accurate results, exact conformity with these figures is not essential. Additional components such as instruments, valves, solenoids and switches may be used to provide additional information and co-ordinate the functions of the component system.

1.4.1. Full Flow Dilution System with Positive Displacement Pump

The Positive Displacement Pump (PDP) full flow dilution system satisfies the requirements of this Appendix by metering the flow of gas through the pump at constant temperature and pressure. The total volume is measured by counting the revolutions made by the calibrated positive displacement pump. The proportional sample is achieved by sampling with pump, flow meter and flow control valve at a constant flow rate. The collecting equipment consists of:

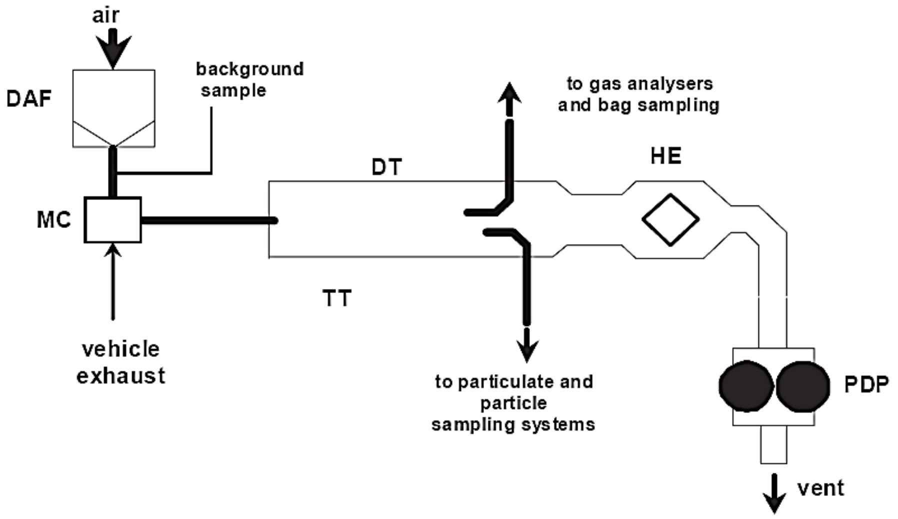


Figure 1
Positive Displacement Pump Dilution System

1.4.1.1. A filter Dilution Air Filter (DAF) for the dilution air, which can be preheated if necessary. This filter shall consist of the following filters in sequence: an optional activated charcoal filter (inlet side), and a High Efficiency Particulate Air (HEPA) filter (outlet side). It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal filter, if used. The purpose of the charcoal filter is to reduce and stabilize the hydrocarbon concentrations of ambient emissions in the dilution air;

1.4.1.2. A Transfer Tube (TT) by which vehicle exhaust is admitted into a dilution tunnel (DT) in which the exhaust gas and dilution air are mixed homogeneously;

1.4.1.3. The Positive Displacement Pump (PDP), producing a constant-volume flow of the air/ exhaust-gas mixture. The PDP revolutions, together with associated temperature and pressure measurement are used to determine the flow rate;

1.4.1.4. A Heat Exchanger (HE) of a capacity sufficient to ensure that throughout the test the temperature of the air/exhaust-gas mixture measured at a point immediately upstream of the positive displacement pump is within 6K of the average operating temperature during the test. This device shall not affect the pollutant concentrations of diluted gases taken off after for analysis.

1.4.1.5. A Mixing Chamber (MC) in which exhaust gas and air are mixed homogeneously, and which may be located close to the vehicle so that the length of the transfer tube (TT) is minimized.

1.4.2. Full Flow Dilution System with Critical Flow Venturi

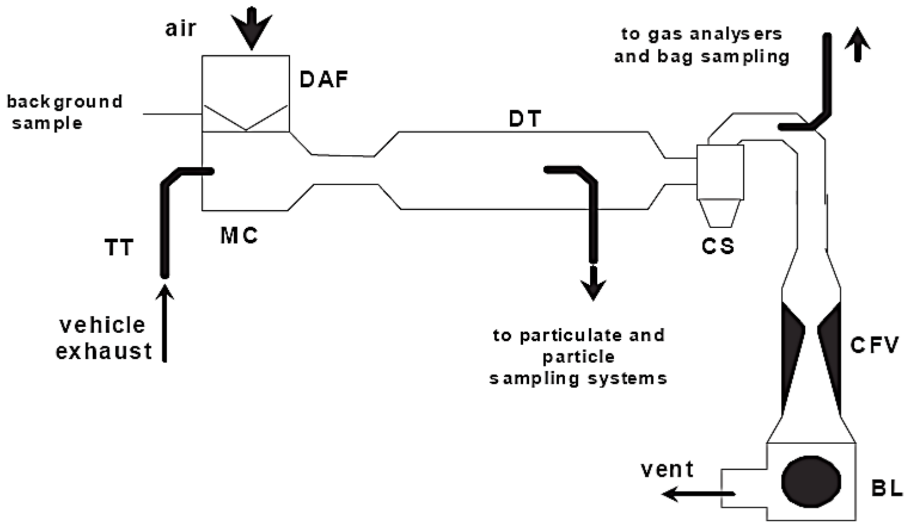


Figure 2
Critical-Flow Venturi Dilution System

The use of a Critical-Flow Venturi (CFV) for the full-flow dilution system is based on the principles of flow mechanics for critical flow. The variable mixture flow rate of dilution and exhaust gas is maintained at sonic velocity which is directly proportional to the square root of the gas temperature. Flow is continually monitored, computed and integrated throughout the test.

The use of an additional critical-flow sampling venturi ensures the proportionality of the gas samples taken from the dilution tunnel. As both pressure and temperature are equal at the two venturi inlets the volume of the gas flow diverted for sampling is proportional to the total volume of diluted exhaust-gas mixture produced, and thus the requirements of this Appendix are met. The collecting equipment consists of:

1.4.2.1. A filter (DAF) for the dilution air, which can be preheated if necessary. This filter shall consist of the following filters in sequence: an optional activated charcoal filter (inlet side), and a High Efficiency Particulate Air (HEPA) filter (outlet side). It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal filter, if used. The purpose of the charcoal filter is to reduce and stabilize the hydrocarbon concentrations of ambient emissions in the dilution air;

1.4.2.2. A Mixing Chamber (MC) in which exhaust gas and air are mixed homogeneously, and which may be located close to the vehicle so that the length of the Transfer Tube (TT) is minimized;

1.4.2.3. A Dilution Tunnel (DT) from which particulates and particles are sampled;

1.4.2.4. Some form of protection for the measurement system may be used e.g. a cyclone separator, bulk stream filter, etc.

1.4.2.5. A measuring Critical-Flow Venturi tube (CFV), to measure the flow volume of the diluted exhaust gas;

1.4.2.6. A blower (BL), of sufficient capacity to handle the total volume of diluted exhaust gas.

2.0. CVS CALIBRATION PROCEDURE

2.1. General Requirements

The CVS system shall be calibrated by using an accurate flow-meter and a restricting device. The flow through the system shall be measured at various pressure readings and the control parameters of the system measured and related to the flows. The flow-metering device shall be dynamic and suitable for the high flow-rate encountered in constant volume sampler testing. The device shall be of certified accuracy traceable to an approved national or international standard.

2.1.1. Various types of flow-meter may be used, e.g. calibrated venturi, laminar flow-meter, calibrated turbine-meter, provided that they are dynamic measurement systems and can meet the requirements of clause 1.3.5 of this Appendix.

2.1.2. The following clauses give details of methods of calibrating PDP and CFV units, using a laminar flow-meter, which gives the required accuracy, together with a statistical check on the calibration validity.

2.2. Calibration of the Positive Displacement Pump (PDP)

2.2.1. The following calibration procedure outlines the equipment, the test configuration and the various parameters that are measured to establish the flow-rate of the CVS pump. All the parameters related to the pump are simultaneously measured with the parameters related to the flow meter which is connected in series with the pump. The calculated flow rate (given in m3/min at pump inlet, absolute pressure and temperature) can then be plotted versus a correlation function that is the value of a specific combination of pump parameters. The linear equation that relates the pump flow and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.

2.2.2. This calibration procedure is based on the measurement of the absolute values of the pump and flow-meter parameters that relate the flow rate at each point. Three conditions shall be maintained to ensure the accuracy and integrity of the calibration curve:

2.2.2.1. The pump pressures shall be measured at tappings on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top centre and bottom centre of the pump drive head plate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials;

2.2.2.2. Temperature stability shall be maintained during the calibration. The laminar flow-meter is sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes of ±1 K in temperature are acceptable as long as they occur over a period of several minutes;

2.2.2.3. All connections between the flow-meter and the CVS pump shall be free of any leakage.

2.2.3 During an exhaust emission test, the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

2.2.4. Figure 3 of this Appendix shows one possible test set-up. Variations are permissible, provided that the Test agency approves them as being of comparable accuracy. If the set-up shown in Figure 8 is used, the following data shall be found within the limits of precision given:

Barometric pressure (corrected)(Pb)	±0.03 kPa
Ambient temperature (T)	±0.2 K
Air temperature at LFE (ETI)	±0.15K
Pressure depression upstream of LFE (EPI)	±0.01 kPa
Pressure drop across the LFE matrix (EDP)	±0.0015 kPa
Air temperature at CVS pump inlet (PTI)	±0.2 K
Air temperature at CVS pump outlet (PTO)	±0.2 K
Pressure depression at CVS pump inlet (PPI)	±0.22 kPa
Pressure head at CVS pump outlet (PPO)	±0.22 kPa
Pump revolutions during test period (n)	±1 min^{-1}
Elapsed time for period (minimum 250 s) (t)	±0.1 s

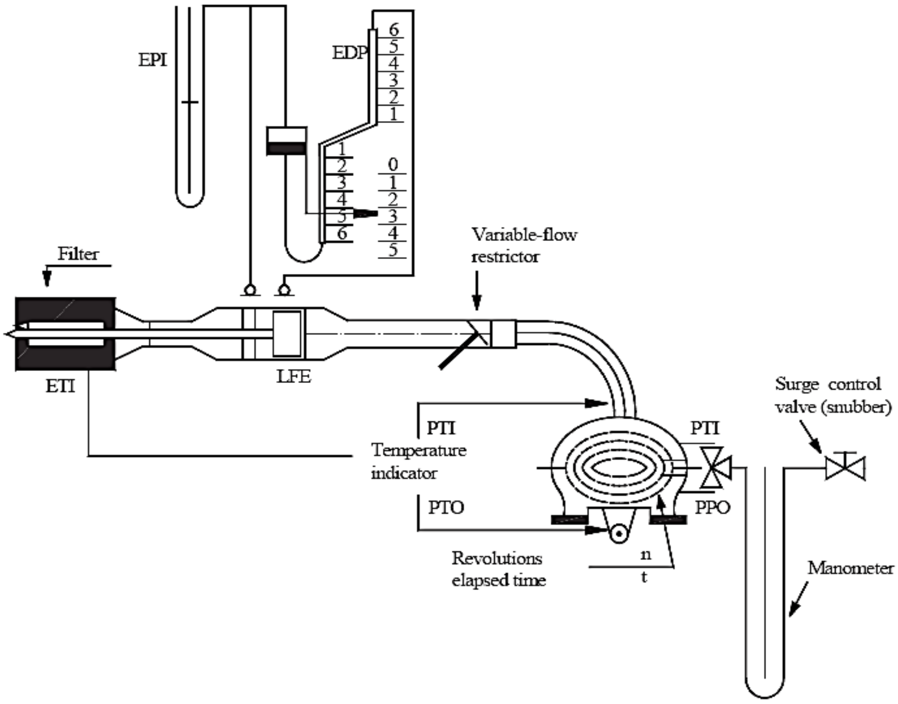


Figure 3
PDP Calibration Configuration

2.2.5. After the system has been connected as shown in Figure 3 of this Appendix, set the variable restrictor in the wide-open position and run the CVS pump for 20 minutes before starting the calibration.

2.2.6. Reset the restrictor valve to a more restricted condition in an increment of pump inlet depression (about 1 kPa) that will yield a minimum of six data points for the total calibration. Allow the system to stabilize for 3 minutes and repeat the data acquisition.

2.2.7. The air flow rate (Qs) at each test point is calculated in standard m3/min from the flow-meter data using the manufacturer's prescribed method.

2.2.8. The air flow-rate is then converted to pump flow (V_0) in m^3 /rev at absolute pump inlet temperature and pressure

$$V_0 = \frac{Q_s}{n} \cdot \frac{T_p}{273.2} \cdot \frac{101.33}{P_p}$$

Where:

V_0 = pump flow rate at Tp and Pp (m^3/rev),

Q_s = air flow at 101.33 kPa and 273.2 K (m^3/min)

T_p = pump inlet temperature (K),

P_p = absolute pump inlet pressure (kPa),

N = pump speed (min^{-1}).

2.2.9. To compensate for the interaction of pump speed pressure variations at the pump and the pump slip rate, the correlation function (X_0) between the pump speed (n), the pressure differential from pump inlet to pump outlet and the absolute pump outlet pressure is then calculated as follows:

$$x_0 = \frac{1}{n}\sqrt{\frac{\Delta P_p}{P_e}}$$

Where:

X_0 = correlation function,

ΔP_p = pressure differential from pump inlet to pump outlet (kPa),

Pe = absolute outlet pressure (PPO + Pb) (kPa).

A linear least-square fit is performed to generate the calibration equations which have the formula:

$V_0 = D_0 - M(X_0)$

$n = A - B\ (\Delta P_p)$

D_0, M, A and B are the slope-intercept constants describing the lines.

2.2.10. A CVS system that has multiple speeds shall be calibrated on each speed used. The calibration curves generated for the ranges shall be approximately parallel and the intercept values (D_0) shall increase as the pump flow range decreases.

2.2.11 If the calibration has been performed carefully, the calculated values from the equation will be within 0.5 % of the measured value of V_0. Values of M will vary from one pump to another. Calibration is performed at pump start-up and after major maintenance.

2.3 Calibration of the Critical-Flow Venturi (CFV)

2.3.1 Calibration of the CFV is based upon the flow equation for a critical venturi:

$$Q_s = \frac{K_v P}{\sqrt{T}}$$

Where:

Qs = flow,

Kv = calibration coefficient,

P = absolute pressure (kPa),

T = absolute temperature (K).

Gas flow is a function of inlet pressure and temperature.

The calibration procedure described below establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

2.3.2 The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

2.3.3 Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given:

Barometric pressure (corrected) (P_b)	±0.03 kPa,
LFE air temperature, flow-meter (ETI)	±0.15 K,
Pressure depression upstream of LFE (EPI)	±0.01 kPa,
Pressure drop across (EDP) LFE matrix	±0.0015 kPa,
Air flow (Q_s)	±0.5 %
CFV inlet depression (PPI)	±0.02 kPa,
Temperature at venturi inlet (T_v)	±0.2 K.

2.3.4 The equipment shall be set up as shown in Figure 4 of this Appendix and checked for leaks. Any leaks between the flow-measuring device and the critical-flow venturi will seriously affect the accuracy of the calibration.

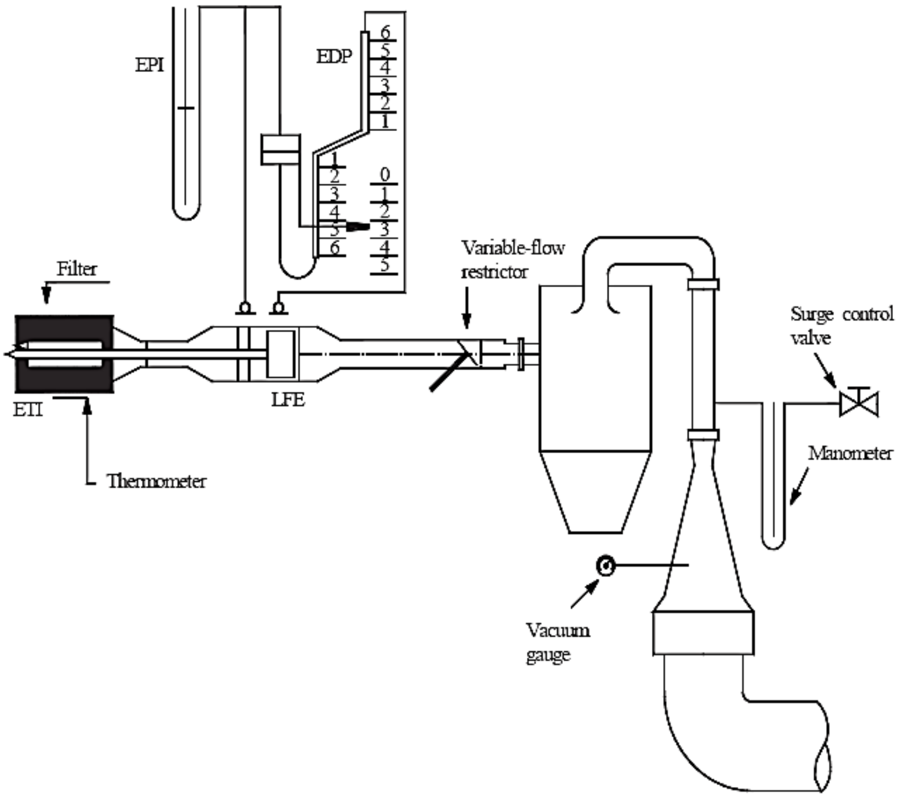


Figure 4

CFV Calibration Configuration

2.3.5. The variable-flow restrictor shall be set to the open position, the blower shall be started and the system stabilized. Data from all instruments shall be recorded.

2.3.6 The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.

2.3.7 The data recorded during the calibration shall be used in the following calculations. The air flow-rate (Qs) at each test point is calculated from the flow-meter data using the manufacturer's prescribed method. Calculate values of the calibration coefficient for each test point:

$$K_v = \frac{Q_s \sqrt{T_v}}{P_v}$$

Where:

Qs = Flow-rate in m^3/min at 273.2 K and 101.33 kPa,

Tv = Temperature at the venturi inlet (K),

Pv = Absolute pressure at the venturi inlet (kPa).

Plot Kv as a function of venturi inlet pressure. For sonic flow, Kv will have a relatively constant value. As pressure decreases (vacuum increases) the venturi becomes unchoked and Kv decreases. The resultant Kv changes are not permissible.

For a minimum of eight points in the critical region, calculate an average K_v and the standard deviation.

If the standard deviation exceeds 0.3 % of the average K_v, take corrective action.

3.0 SYSTEM VERIFICATION PROCEDURE

3.1 General Requirements

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system whilst it is being operated as if during a normal test and then analyzing and calculating the pollutant mass according to the formula in clause 6.13 of Chapter 3 of this Part except that the density of propane shall be taken as 1.967 grams per litre at standard conditions. The following two techniques are known to give sufficient accuracy.

The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured is 5 %

3.2 Critical Flow Orifice (CFO) Method

3.2.1 Metering a constant flow of pure gas (CO or C_3H_8) using a critical flow orifice device.

3.2.2 A known quantity of pure gas (CO or C_3H_8) is fed into the CVS system through the calibrated critical orifice. If the inlet pressure is high enough, the flow-rate (q), which is adjusted by means of the critical flow orifice, is independent of orifice outlet pressure (critical flow). If deviations exceeding 5 % occur, the cause of the malfunction shall be determined and corrected. The CVS system is operated as in an exhaust emission test for about 5 to 10 minutes. The gas collected in the sampling bag is analyzed by the usual equipment and the results compared to the concentration of the gas samples which was known beforehand.

3.3 Gravimetric Method

3.3.1 Metering a limited quantity of pure gas (CO or C_3H_8) by means of a gravimetric technique.

3.3.2 The following gravimetric procedure may be used to verify the CVS system.

The weight of a small cylinder filled with either carbon monoxide or propane is determined with a precision of ±0.01 g. For about 5 to 10 minutes, the CVS system is operated as in a normal exhaust emission test, while CO or propane is injected into the system. The quantity of pure gas involved is determined by means of differential weighing. The gas accumulated in the bag is then analyzed by means of the equipment normally used for exhaust-gas analysis. The results are then compared to the concentration figures computed previously.

CHAPTER 5 - APPENDIX 1

VERIFICATION OF SIMULATED INERTIA

1.0 OBJECT

The method described in this Appendix makes it possible to check that the simulated total inertia of the dynamometer is carried out satisfactorily in the running phase of the operating cycle. The manufacturer of the dynamometer shall specify a method for verifying the specifications according to clause 3 to this Appendix.

2.0 PRINCIPLE

2.1 Drawing-up Working Equations

Since the dynamometer is subjected to variations in the rotating speed of the roller(s), the force at the surface of the roller(s) can be expressed by the formula:

$$F = I \cdot \gamma = I_M \cdot \gamma + F_1$$

Where:

F = force at the surface of the roller(s),

I = total inertia of the dynamometer (equivalent inertia of the vehicle: see the Table 1 of Chapter 3 of this Part),

I_M = inertia of the mechanical masses of the dynamometer,

γ = tangential acceleration at roller surface,

F_1 = inertia force.

Note: An explanation of this formula with reference to dynamometers with mechanically simulated inertia is appended.

Thus, total inertia is expressed as follows:

$$I = I_m + F_1/\gamma$$

Where:

I_m can be calculated or measured by traditional methods,

F_1 can be measured on the dynamometer,

γ can be calculated from the peripheral speed of the rollers.

The total inertia (I) will be determined during an acceleration or deceleration test with values higher than or equal to those obtained on an operating cycle.

2.2 Specification for the Calculation of Total Inertia

The test and calculation methods shall make it possible to determine the total inertia I with a relative error ($\Delta I/I$) of less than ±2 %

3.0 SPECIFICATION

3.1 The mass of the simulated total inertia I shall remain the same as the theoretical value of the equivalent inertia (see Table 1 of Chapter 3 of this Part) within the following limits:

3.1.1 ±5 % of the theoretical value for each instantaneous value;

3.1.2 ±2 % of the theoretical value for the average value calculated for each sequence of the cycle.

The limit given in clause 3.1.1 above is brought to ±50 % for one second when starting and, for vehicles with manual transmission, for two seconds during gear changes.

4.0 VERIFICATION PROCEDURE

4.1 Verification is carried out during each test throughout the cycle defined in clause 5.1 of Chapter 3 of this Part.

4.2 However, if the requirements of clause 3. above are met, with instantaneous accelerations which are at least three times greater or smaller than the values obtained in the sequences of the theoretical cycle, the verification described above will not be necessary.

CHAPTER 5 - APPENDIX 2

MEASUREMENT OF VEHICLE ROAD LOAD RESISTANCE TO PROGRESS OF A VEHICLE MEASUREMENT METHOD ON THE ROAD SIMULATION ON A CHASSIS DYNAMOMETER

1.0 OBJECT OF THE METHODS

The object of the methods defined below is to measure the resistance to progress of a vehicle at stabilized speeds on the road and to simulate this resistance on a dynamometer, in accordance with the conditions set out in clause 6.1 of Chapter 3 of this Part.

2.0 DEFINITION OF THE ROAD

The road shall be level and sufficiently long to enable the measurements specified in this Appendix to be made. The longitudinal slope shall be constant to within ± 0.1% and shall not exceed 1.5%.

3.0 ATMOSPHERIC CONDITIONS

3.1 **Wind**

Testing shall be limited to wind speeds averaging less than 3 m/s with peak speeds of less than 5 m/s. In addition, the vector component of the wind speed across the test road shall be less than 2 m/s as average. Wind velocity shall be measured 0.7 m above the road surface.

3.2 **Humidity**

The road shall be dry.

3.3 **Pressure and Temperature**

Air density at the time of the test shall not deviate by more than ±7.5% from the reference conditions, P = 100 kPa and T = 293.2 K.

4.0 VEHICLE PREPARATION

4.1 **Selection of the test vehicle**

If not all variants of a vehicle type are measured, the following criteria for the selection of the test vehicle shall be used.

4.1.1 Body

If there are different types of body, the test shall be performed on the least aerodynamic body. The manufacturer shall provide the necessary data for the selection (Physical test / CAE data).

4.1.2 Tyres

The choice of tyres shall be based on the rolling resistance. The tyres with the highest rolling resistance shall be chosen, measured according to ISO 28580 or AIS-142 or UN R117.

If there are more than three tyre rolling resistances, the tyre with the second highest rolling resistance shall be chosen.

The rolling resistance characteristics of the tyres fitted to production vehicles shall reflect those of the tyres used for type approval.

4.1.3 Testing mass

The testing mass shall be the reference mass of the vehicle with the highest inertia range.

4.1.4 Engine

The test vehicle shall have the largest heat exchanger(s).

4.1.5 Transmission

A test shall be carried out with each type of the following transmission: Front-wheel drive,

Rear-wheel drive,

Full-time 4 x 4,

Part-time 4 x 4,

Automatic gearbox,

Manual gearbox.

4.2 **Running-in**

The vehicle shall be in normal running order and adjustment after having been run-in for at least 3,000 km. The tyres shall be run-in at the same time as the vehicle or have a tread depth within 90 and 50% of the initial tread depth.

4.3 **Verifications**

The following checks shall be made in accordance with the manufacturer's specifications for the use considered:

Wheels, wheel trims, tyres (make, type, pressure), front axle geometry, brake adjustment (elimination of parasitic drag), lubrication of front and rear axles, adjustment of the suspension and vehicle level, etc.

4.4 Preparation for the test

4.4.1 The vehicle shall be loaded to its reference mass. The level of the vehicle shall be that obtained when the centre of gravity of the load is situated midway between the "R" points of the front outer seats and on a straight line passing through those points.

4.4.2 In the case of road tests, the windows of the vehicle shall be closed. Any covers of air climatisation systems, headlamps, etc. shall be in the non-operating position.

4.4.3 The vehicle shall be clean.

4.4.4 Immediately prior to the test, the vehicle shall be brought to normal running temperature in an appropriate manner.

5.0 METHODS

5.1 **Energy variation during coast-down method**

5.1.1 On the road

5.1.1.1 Test equipment and error

Time shall be measured to an error lower than ± 0.1 s. Speed shall be measured to an error lower than ± 2%.

During the test, elapsed time and vehicle speed shall be measured and recorded at a minimum frequency of 1Hz

5.1.1.2 **Test procedure**

5.1.1.2.1 Accelerate the vehicle to a speed 10 km/h higher than the chosen test speed V.

5.1.1.2.2 Place the gearbox in "neutral" position.

5.1.1.2.3 For each reference speed Point v_j, measure the time taken (ΔT_{aj}) for the vehicle to decelerate from speed

$v_2 = v_j + \Delta v$ km/h to $v_1 = v_j - \Delta v$ km/h

where:

Δv is equal to 5 km/h

v_j is each of the reference speed [km/h] points as indicated in the following table:

20	30	40	50	60	70	80	90	100	110	120

5.1.1.2.4 Perform the same test in the opposite direction: ΔT_{bj}

5.1.1.2.5 These measurements shall be carried out in opposite directions until, for each reference speed v_j, a minimum of three consecutive pairs of measurements have been obtained which satisfy the statistical accuracy p_j, in per cent, as defined below.

$$Pj = \frac{h.sj}{\sqrt{n}} * \frac{100}{\Delta Tj} \leq 3\%$$

where:

p_j is the statistical accuracy of the measurements performed at reference speed v_j;

n is the number of pairs of measurements;

ΔT_j is the mean coast down time at reference speed v_j in seconds, given by the equation:

$$\Delta T_j = \frac{1}{n}\sum_{i=1}^{n} \Delta T_{ji}$$

where ΔT_{ji} is the harmonic mean coast down time of the i_{th} pair of measurements at velocity

v_j, seconds [s], given by the equation:

$$\Delta T_{ji} = \frac{2}{\left(\frac{1}{\Delta T_{aji}}\right) + \left(\frac{1}{\Delta T_{bji}}\right)}$$

where ΔT_{aji} and ΔT_{bji} are the coast down times of the i_{th} measurement at reference speed v_j,

in seconds [s], in opposite directions a and b, respectively;

s_j is the standard deviation, in seconds [s], defined by:

$$S_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (\Delta T_{ji} - \Delta T_j)^2}$$

h is a coefficient given in the following table

Coefficient h as function of n

n	**h**	**n**	**h**	**n**	**h**
3	4.3	13	2.2	23	2.1
4	3.2	14	2.2	24	2.1
5	2.8	15	2.2	25	2.1
6	2.6	16	2.1	26	2.1
7	2.5	17	2.1	27	2.1
8	2.4	18	2.1	28	2.1
9	2.3	19	2.1	29	2.0
10	2.3	20	2.1	30	2.0
11	2.2	21	2.1		
12	2.2	22	2.1		

5.1.1.2.6 If during a measurement in one direction any external factor or driver action occurs which influences the road load test, that measurement and the corresponding measurement in the opposite direction shall be rejected.

5.1.1.2.7 The total resistances, F_{aj} and F_{bj}, at reference speed v_j in directions a and b, are determined by the equations:

$$F_{aj} = \frac{1}{3.6} * M * \frac{2 * \Delta V}{\Delta T_{aj}}$$

And

$$F_{bj} = \frac{1}{3.6} * M * \frac{2 * \Delta V}{\Delta T_{bj}}$$

where:

F_{aj} = total resistance at reference speed, j, in direction a, [N];

F_{bj} = total resistance at reference speed, j, in direction b, [N];

M = reference mass, [kg];

Δv = delta speed around vj, taken according to 5.1.1.2.3 of this Appendix.

ΔT_{aj} and ΔT_{bj} = mean coast down times in directions a and b, respectively, corresponding to reference speed vj, in seconds [s], given by the following equations:

$$\Delta T_{aj} = \frac{1}{n} \sum_{i=1}^{n} \Delta T_{aji}$$

And

$$\Delta T_{bj} = \frac{1}{n} \sum_{i=1}^{n} \Delta T_{bji}$$

5.1.1.2.8 The following equation shall be used to compute the average total resistance:

$$F_j = \left(\frac{(F_{aj} + F_{bj})}{2} \right)$$

5.1.1.2.9 For each reference speed v_j calculate the power (P_j), [kW], by the formula:

$$P_j = (F_j \cdot v_j)/1{,}000$$

where:

F_j is the average resistance at reference speed, j, [N];

v_j is the reference speed, j, [m/s], defined in 5.1.1.2.3. of this Appendix

5.1.1.2.10 The complete power curve (P), [kW], as a function of speed, [km/h], shall be calculated with a least squares statistical regression analysis.

Final results shall be recorded as regression coefficients of force equation in the form either –

$F = F_0 + (F_1*V) + (F_2*V^2)$ or

$F = F_0 + (F_2*V^2)$

where, F_0, F_1, F_2 are regression coefficients

5.1.1.2.11 The power (P) determined on the track shall be corrected to the reference ambient conditions as follows:

$P_{Corrected} = K \cdot P_{Measured}$

$$K = \frac{R_R}{R_T} \cdot \left[1 + K_R\left(t - t_0\right)\right] + \frac{R_{AERO}}{R_T} \cdot \frac{(\rho_0)}{\rho}$$

Where:

R_R = Rolling resistance at speed V,

R_{AERO} = aerodynamic drag at speed V,

R_T = Total driving resistance = $R_R + R_{AERO}$,

K_R = Temperature correction factor of rolling resistance, taken to be equal to 8.64 x 10^{-3}/°C, or the manufacturer's correction factor that is approved by the Test Agency

t = Road test ambient temperature in °C,

t_0 = Reference ambient temperature = 20° C,

ρ = Air density at the test conditions

ρ_0 = Air density at the reference conditions (20° C, 100 kPa)

The ratios R_R/R_T and R_{AERO}/R_T shall be specified by the vehicle manufacturer based on the data normally available to the company.

If these values are not available, subject to the agreement of the manufacturer and the Test Agency concerned, the figures for the rolling/total resistance given by the following formula may be used:

$$\frac{R_R}{R_T} = a \cdot M + b$$

Where:

M = Vehicle mass in kg and for each speed the coefficients a and b are shown in the following table:

km/h	a	b
120	1.57E-04	0.14
110	1.60E-04	0.16
100	1.63E-04	0.18
90	1.71E-04	0.21
80	1.85E-04	0.23
70	1.91E-04	0.28
60	1.96E-04	0.33
50	1.86E-04	0.42
40	1.59E-04	0.54
30	1.25E-04	0.67
20	7.24E-05	0.82

5.1.2 On the dynamometer

5.1.2.1 Measurement equipment and accuracy

The equipment shall be identical to that used on the road.

5.1.2.2 Test procedure

5.1.2.2.1 Install the vehicle on the test dynamometer.

5.1.2.2.2 Adjust the tyre pressure (cold) of the driving wheels as required by the dynamometer.

5.1.2.2.3 Adjust the equivalent inertia of the dynamometer.

5.1.2.2.4 Bring the vehicle and dynamometer to operating temperature in a suitable manner

5.1.2.2.5 Carry out the operations specified in clause 5.1.1.2. of this Appendix (with the exception of clauses 5.1.1.2.4.), replacing M by I in the formula set out in clause 5.1.1.2.7 of this Appendix.

5.1.2.2.6 Adjust the brake to reproduce the corrected power (clause 5.1.1.2.11 of this Appendix.) and to take into account the difference between the vehicle mass (M) on the track and the equivalent inertia test mass (I) to be used. This may be done by calculating the mean corrected road coast down time from V_2 to V_1 and reproducing the same time on the dynamometer by the following relationship:

$$T_{corrected} = \frac{T_{measured}}{K} \cdot \frac{I}{M}$$

K = value specified in clause 5.1.1.2.11 of this Appendix.

5.1.2.2.7 The power Pa to be absorbed by the dynamometer shall be determined in order to enable the same power (clause 5.1.1.2.11. of this Appendix) to be reproduced for the same vehicle on different days.

5.2 Torque measurements method at constant speed

5.2.1 On the road

5.2.1.1 Measurement equipment and error

Torque measurement shall be carried out with an appropriate measuring device accurate to within ±2%.

Speed measurement shall be accurate to within ±2%

5.2.1.2 Test procedure

5.2.1.2.1 Bring the vehicle to the chosen stabilized speed V.

5.2.1.2.2 Record the torque C_t and speed over a period of at least 20 seconds. The accuracy of the data recording system shall be at least ±1 Nm for the torque and ±0.2 km/h for the speed.

5.2.1.2.3 Differences in torque C_t and speed relative to time shall not exceed 5% for each second of the measurement period.

5.2.1.2.4 The torque C_{t1} is the average torque derived from the following formula:

$$C_{t1} = \frac{1}{\Delta t} \int_{t}^{t+\Delta t} C(t)dt$$

5.2.1.2.5 The test shall be carried out three times in each direction. Determine the average torque from these six measurements for the reference speed. If the average speed deviates by more than 1 km/h from the reference speed, a linear regression shall be used for calculating the average torque.

5.2.1.2.6 Determine the average of these two torques C_{t1} and C_{t2}, i.e. C_t.

5.2.1.2.7 The average torque C_T determined on the track shall be corrected to the reference ambient conditions as follows:

$$C_{Tcorrected} = K \cdot C_{Tmeasured}$$

Where K has the value specified in clause 5.1.1.2.11. of this Appendix.

5.2.5 On the dynamometer

5.2.2.1 Measurement equipment and error

The equipment shall be identical to that used on the road.

5.2.2.2 Test procedure

5.2.2.2.1 Perform the operations specified in clauses 5.1.2.2.1 to 5.1.2.2.4 of this Appendix.

5.2.2.2.2 Perform the operations specified in clauses 5.2.1.2.1 to 5.2.1.2.4 of this Appendix.

5.2.2.2.3 Adjust the power absorption unit to reproduce the corrected total track torque indicated in clause 5.2.1.2.7 of this Appendix.

5.2.2.2.4 Proceed with the same operations as in clause 5.1.2.2.7 of this Appendix, for the same purpose.

CHAPTER 6

CALIBRATION OF EQUIPMENT FOR EVAPORATIVE EMISSION TESTING

1.0 CALIBRATION FREQUENCY AND METHODS

1.1 All equipment shall be calibrated before its initial use and then calibrated as often as necessary and in any case in the month before type approval testing. The calibration methods to be used are described in this Chapter.

1.2 Normally the series of temperatures which are mentioned first shall be used. The series of temperatures within square brackets may alternatively be used.

2.0 CALIBRATION OF THE ENCLOSURE

2.1 Initial Determination of Internal Volume of the Enclosure

2.1.1 Before its initial use, the internal volume of the chamber shall be determined as follows:

The internal dimensions of the chamber are carefully measured, allowing for any irregularities such as bracing struts. The internal volume of the chamber is determined from these measurements.

For variable-volume enclosures, the enclosure shall be latched to a fixed volume when the enclosure is held at an ambient temperature of 303 K (30°C) [(302 K (29 °C)]. This nominal volume shall be repeatable within ±0.5% of the reported value.

2.1.2 The net internal volume is determined by subtracting 1.42 m^3 from the internal volume of the chamber. Alternatively the volume of the test vehicle with the luggage compartment and windows open may be used instead of the 1.42 m^3.

2.1.3 The chamber shall be checked as in clause 2.3 of this Chapter. If the propane mass does not correspond to the injected mass to within ±2%, then corrective action is required.

2.2 Determination of Chamber Background Emissions

This operation determines that the chamber does not contain any materials that emit significant amounts of hydrocarbons. The check shall be carried out at the enclosure's introduction to service, after any operations in the enclosure which may affect background emissions and at a frequency of at least once per year.

2.2.1 Variable-volume enclosures may be operated in either latched or unlatched volume configuration, as described in clause 2.1.1. of this Chapter, ambient temperatures shall be maintained at 308K ± 2K. (35 ± 2°C) [309K ± 2K (36 ± 2°C)], throughout the 4-hour period mentioned below.

2.2.2 Fixed volume enclosures shall be operated with the inlet and outlet flow streams closed.

Ambient temperatures shall be maintained at 308 K ±2 K (35 ±2 °C) [309 K ±2 K (36 ±2 °C) throughout the 4-hour period mentioned below.

2.2.3 The enclosure may be sealed and the mixing fan operated for a period of up to 12 hours before the 4-hour background sampling period begins.

2.2.4 The analyzer (if required) shall be calibrated, then zeroed and spanned.

2.2.5 The enclosure shall be purged until a stable hydrocarbon reading is obtained, and the mixing fan turned on if not already on.

2.2.6 The chamber is then sealed and the background hydrocarbon concentration, temperature and barometric pressure are measured. These are the initial readings C_{HCi}, P_i, T_i used in the enclosure background calculation.

2.2.7 The enclosure is allowed to stand undisturbed with the mixing fan on for a period of 4 hours.

2.2.8 At the end of this time the same analyzer is used to measure the hydrocarbon concentration in the chamber. The temperature and the barometric pressure are also measured. These are the final readings CHCf, Pf, Tf.

2.2.9 The change in mass of hydrocarbons in the enclosure shall be calculated over the time of the test in accordance with clause 2.4 of this Chapter and shall not exceed 0.05 g.

2.3 Calibration and Hydrocarbon Retention Test of the Chamber

The calibration and hydrocarbon retention test in the chamber provides a check on the calculated volume in clause 2.1 of this Chapter and also measures any leak rate. The enclosure leak rate shall be determined at the enclosure's introduction to service, after any operations in the enclosure which may affect the integrity of the enclosure, and at least monthly thereafter. If six consecutive monthly retention checks are successfully completed without corrective action, the enclosure leak rate may be determined quarterly thereafter as long as no corrective action is required.

2.3.1 The enclosure shall be purged until a stable hydrocarbon concentration is reached. The mixing fan is turned on, if not already switched on. The hydrocarbon analyzer is zeroed, calibrated if required, and spanned.

2.3.2 On variable-volume enclosures, the enclosure shall be latched to the nominal volume position. On fixed-volume enclosures the outlet and inlet flow streams shall be closed.

2.3.3 The ambient temperature control system is then turned on (if not already on) and adjusted for an initial temperature of 308 K (35 °C) [309 K (36 °C)].

2.3.4 When the enclosure stabilizes at 308 K ±2 K (35 ±2 °C) [309 K ±2 K (36 ±2 °C)], the enclosure is sealed and the background concentration, temperature and barometric pressure measured. These are the initial readings C_{HCi}, P_i, T_i used in the enclosure calibration.

2.3.5 A quantity of approximately 4 grams of propane is injected into the enclosure. The mass of propane shall be measured to an accuracy and precision of ±2% of the measured value.

2.3.6 The contents of the chamber shall be allowed to mix for 5 minutes and then the hydrocarbon concentration, temperature and barometric pressure are measured. These are the readings C_{HCf}, P_f, T_f for the calibration of the enclosure as well as the initial readings C_{HCi}, P_i, T_i for the retention check.

2.3.7 Based on the readings taken according to clauses 2.3.4 and 2.3.6 of this Chapter and the formula in clause 2.4 of this Chapter, the mass of propane in the enclosure is calculated. This shall be within ±2% of the mass of propane measured in clause 2.3.5 of this Chapter.

2.3.8 For variable volume enclosures the enclosure shall be unlatched from the nominal volume configuration. For fixed-volume enclosures, the outlet and inlet flow streams shall be opened.

2.3.9 The process is then begun of cycling the ambient temperature from 308 K (35°C) to 293 K (20°C) and back to 308 K (35°C) [308.6 K (35.6°C) to 295.2 K (22.2°C) and back to 308.6 K (35.6 °C)] over a 24-hour period according to the profile [alternative profile] specified in Table 1 of this Chapter within 15 minutes of sealing the enclosure. (Tolerances as specified in clause 5.7.1of Chapter 11 of this Part).

2.3.10 At the completion of the 24-hour cycling period, the final hydrocarbon concentration, temperature and barometric pressure are measured and recorded. These are the final readings C_{HCf}, P_f, T_f for the hydrocarbon retention check.

2.3.11 Using the formula in clause 2.4 of this Chapter, the hydrocarbon mass is then calculated from the readings taken in clauses 2.3.10 and 2.3.6 of this Chapter. The mass may not differ by more than 3% from the hydrocarbon mass given in clause 2.3.7 of this Chapter.

2.4 Calculations

The calculation of net hydrocarbon mass change within the enclosure is used to determine the chamber's hydrocarbon background and leak rate. Initial and final readings of hydrocarbon concentration, temperature and barometric pressure are used in the following formula to calculate the mass change.

$$M_{HC} = K * V * 10^{-4}\left(\frac{C_{HC,f} * P_f}{T_f} - \frac{C_{HC,i} * P_i}{T_i}\right) + M_{HC,out} - M_{HC,i}$$

Where:

M_{HC} =	=	Hydrocarbon mass in grams,
$M_{HC,out}$	=	Mass of hydrocarbons exiting the enclosure, in the case of fixed-volume enclosures for diurnal emission testing (grams),
$M_{HC,i}$	=	Mass of hydrocarbons entering the enclosure when a fixed volume enclosure is used for testing diurnal emissions (grams),
C_{HC} =	=	Hydrocarbon concentration in the enclosure (ppm carbon (Note: ppm carbon = ppm propane x 3)),
V	=	Enclosure volume in cubic meters,
T	=	ambient temperature in the enclosure, (K),
P	=	barometric pressure, (kPa)
K	=	17.6

Where:

i	=	is the initial reading,
f	=	is the final reading.

3.0. CHECKING OF FID HYDROCARBON ANALYZER

3.1. Detector Response Optimization

The FID shall be adjusted as specified by the instrument manufacturer. Propane in air should be used to optimize the response on the most common operating range.

3.2. **Calibration of the HC Analyser**

The analyser should be calibrated using propane in air and purified synthetic air (see clause 3.2 of Chapter 7 of this Part). Establish a calibration curve as described in clauses 4.1 to 4.5 of this Chapter.

3.3. Oxygen Interference Check and Recommended Limits

The response factor (Rf) for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas cylinder concentration, expressed as ppm C1. The concentration of the test gas shall be at a level to give a response of approximately 80% of full-scale deflection, for the operating range. The concentration shall be known, to an accuracy of ±2% in reference to a gravimetric standard expressed in volume. In addition the gas cylinder shall be preconditioned for 24 hours at a temperature between 293 K and 303 K (20 and 30 °C).

Response factors should be determined when introducing an analyser into service and thereafter at major service intervals. The reference gas to be used is propane with balance purified air which is taken to give a response factor of 1.00.

The test gas to be used for oxygen interference and the recommended response factor range are given below:

Propane and nitrogen: $0.95 \leq Rf \leq 1.05$.

4.0. CALIBRATION OF THE HYDROCARBON ANALYZER

Each of the normally used operating ranges are calibrated by the following procedure:

4.1. Establish the calibration curve by at least five calibration points spaced as evenly as possible over the operating range. The nominal concentration of the calibration gas with the highest concentrations to be at least 80% of the full scale.

4.2. Calculate the calibration curve by the method of least squares. If the resulting polynomial degree is greater than 3, then the number of calibration points shall be at least the number of the polynomial degree plus 2.

4.3. The calibration curve shall not differ by more than 2% from the nominal value of each calibration gas.

4.4. Using the coefficients of the polynomial derived from clause 3.2 of this Chapter, a table of indicated reading against true concentration shall be drawn up in steps of no greater than 1% of full scale. This is to be carried out for each analyzer range calibrated. The table shall also contain other relevant data such as:

(a) Date of calibration, span and zero potentiometer readings (where applicable);
(b) Nominal scale;
(c) Reference data of each calibration gas used;
(d) The actual and indicated value of each calibration gas used together with the percentage differences;
(e) FID fuel and type;
(f) FID air pressure.

4.5 If it can be shown to the satisfaction of the Test Agency that alternative technology (e.g. computer, electronically controlled range switch) can give equivalent accuracy, then those alternatives may be used

Table 1

Diurnal ambient temperature profile for the calibration of the enclosure and the diurnal emission test			Alternative diurnal ambient temperature profile calibration of the enclosure	
Time (hours)		Temperature (°C)	Time (hours)	Temperature (°C)
Calibration	Test			
13	0/24	20.0	0	
14	1	20.2	1	
15	2	20.5	2	
16	3	21.2	3	
17	4	23.1	4	
18	5	25.1	5	
19	6	27.2	6	
20	7	29.8	7	
21	8	31.8	8	
22	9	33.3	9	
23	10	34.4	10	
24/0	11	35.0	11	
1	12	34.7	12	
2	13	33.8	13	
3	14	32.0	14	
4	15	30.0	15	
5	16	28.4	16	
6	17	26.9	17	
7	18	25.2	18	
8	19	24.0	19	
9	20	23.0	20	
10	21	22.0	21	
11	22	20.8	22	
12	23	20.2	23	
			24	

CHAPTER 7

GASEOUS EMISSIONS MEASUREMENT EQUIPMENT

1.0 SPECIFICATION

1.1 System Overview

A continuously proportional sample of the diluted exhaust gases and the dilution air shall be collected for analysis.

Mass gaseous emissions shall be determined from the proportional sample concentrations and the total volume measured during the test. The sample concentrations shall be corrected to take account of the pollutant content of the ambient air.

1.2 Sampling System Requirements

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

1.2.2 The flow rate shall not deviate from the average by more than ±2%.

1.2.3 The sampling rate shall not fall below 5 litres per minute and shall not exceed 0.2% of the flow rate of the dilute exhaust gases. An equivalent limit shall apply to constant-mass sampling systems.

1.2.4 A sample of the dilution air shall be taken at a constant flow rate near the ambient air- inlet (after the filter if one is fitted).

1.2.5 The dilution air sample shall not be contaminated by exhaust gases from the mixing area.

1.2.6 The sampling rate for the dilution air shall be comparable to that used in the case of the dilute exhaust gases.

1.2.7 The materials used for the sampling operations shall be such as not to change the pollutant concentration.

1.2.8 Filters may be used in order to extract the solid particles from the sample.

1.2.9 The various valves used to direct the exhaust gases shall be of a quick- adjustment, quick-acting type.

1.2.10 Quick-fastening gas-tight connections may be used between the three way valves and the sampling bags, the connections sealing themselves automatically on the bag side. Other systems may be used for conveying the samples to the analyzer (three-way stop valves, for example).

1.2.11 **Storage of the sample**

The gas samples shall be collected in sampling bags of sufficient capacity not to impede the sample flow; the bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples by more than ± 2% after 20 minutes (for instance laminated polyethylene/polyamide films or fluorinated poly hydrocarbons).

1.2.12 **Hydrocarbon Sampling System – Diesel Engines**

1.2.12.1 The hydrocarbon sampling system shall consist of a heated sampling probe, line, filter and pump. The sampling probe shall be installed at the same distance from the exhaust gas inlet as the particulate sampling probe, in such a way that neither interferes with samples taken by the other. It shall have a minimum internal diameter of 4 mm.

1.2.12.2 All heated parts shall be maintained at a temperature of 463 K (190 °C) ±10 K by the heating system.

1.2.12.3 The average concentration of the measured hydrocarbons shall be determined by integration.

1.2.12.4 The heated sampling line shall be fitted with a heated filter (F_H) 99% efficient with particles ≥ 0.3 µm, to extract any solid particles from the continuous flow of gas required for analysis.

1.2.12.5 The sampling system response time (from the probe to the analyzer inlet) shall be no more than 4 seconds.

1.2.12.6 The HFID shall be used with a constant flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CVS volume flow is made.

1.3 **Gas Analysis Requirements**

1.3.1 Carbon Monoxide (CO) and Carbon Dioxide (CO_2) Analyses:

1.3.2 Analyzers shall be of the non-dispersive infra-red (NDIR) absorption type.

Total Hydrocarbons (THC) Analysis - Spark-Ignition Engines:

The analyzer shall be of the flame ionization (FID) type calibrated with propane gas expressed equivalent to carbon atoms (C1).

1.3.3 Total Hydrocarbons (THC) Analysis - Compression-Ignition Engines:

The analyzer shall be of the flame ionization type with detector, valves, pipework, etc., heated to 463 K (190 °C) ±10 K (HFID). It shall be calibrated with propane gas expressed equivalent to carbon atoms (C1).

1.3.4 Nitrogen oxide (NOx) Analysis:

The analyzer shall be either of the Chemi-Luminescent Analyzer (CLA) or of the Non-Dispersive Ultra-Violet Resonance Absorption (NDUVR) type, both with NOx-NO converters.

1.3.5 Methane (CH4) Analysis:

The analyzer shall be either a gas chromatograph combined with a FID type or FID with a non-methane cutter type, calibrated with methane gas expressed as equivalent to carbon atoms (C1).

1.3.6 Water (H_2O) Analysis:

The analyser shall be of the NDIR absorption type. The NDIR shall be calibrated either with water vapour or with propylene (C_3H_6). If the NDIR is calibrated with water vapour, it shall be ensured that no water condensation can occur in tubes and connections during the calibration process. If the NDIR is calibrated with propylene, the manufacturer of the analyser shall provide the information for converting concentration of propylene to its corresponding concentration of water vapour. The values for conversion shall be periodically checked by the manufacturer of the analyser, and at least once per year.

1.3.7 Hydrogen (H_2) Analysis:

The analyzer shall be of the sector field mass spectrometry type, calibrated with hydrogen.

1.3.8 The analyzers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants.

1.3.9 Measurement error shall not exceed ±2% (intrinsic error of analyzer) disregarding the true value for the calibration gases.

1.3.10 For concentrations of less than 100 ppm, the measurement error shall not exceed ±2 ppm.

1.3.11 The ambient air sample shall be measured on the same analyzer with an appropriate range.

1.3.11 No gas drying device shall be used before the analyzers unless shown to have no effect on the pollutant content of the gas stream.

1.4 Recommended System Descriptions

Figure 1 of this Chapter is a schematic drawing of the system for gaseous emissions sampling.

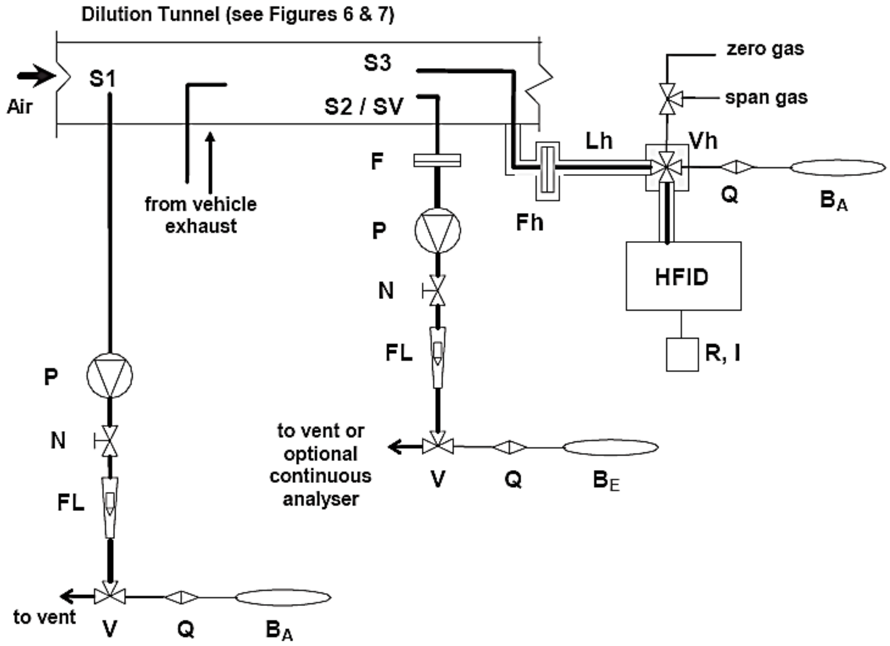


Figure 1
Gaseous Emissions Sampling Schematic

1.4.1 The components of the system are as follows:

Two sampling probes (S1 and S2) for continuous sampling of the dilution air and of the diluted exhaust-gas/air mixture;

1.4.2 A filter (F), to extract solid particles from the flows of gas collected for analysis;

1.4.3 Pumps (P), to collect a constant flow of the dilution air as well as of the diluted exhaust-gas/air mixture during the test;

1.4.4 Flow controller (N), to ensure a constant uniform flow of the gas samples taken during the course of the test from sampling probes S1 and S2 (for PDP-CVS) and flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis (approximately 10 litres per minute);

1.4.5 Flow meters (FL), for adjusting and monitoring the constant flow of gas samples during the test;

1.4.6 Quick-acting valves (V), to divert a constant flow of gas samples into the sampling bags or to the outside vent;

1.4.7 Gas-tight, quick-lock coupling elements (Q) between the quick-acting valves and the sampling bags; the coupling shall close automatically on the sampling-bag side; as an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance);

1.4.8 Bags (B), for collecting samples of the diluted exhaust gas and of the dilution air during the test;

1.4.9 A sampling critical-flow venturi (SV), to take proportional samples of the diluted exhaust gas at sampling probe S2 A (CFV-CVS only);

1.4.10 A scrubber (PS), in the sampling line (CFV-CVS only);

1.4.11 Components for hydrocarbon sampling using HFID:

Fh is a heated filter,

S3 is a sampling point close to the mixing chamber,

Vh is a heated multi-way valve,

Q is a quick connector to allow the ambient air sample BA to be analyzed on the HFID,

FID is a heated flame ionization analyzer,

R and I are a means of integrating and recording the instantaneous hydrocarbon concentrations,

Lh is a heated sample line.

2.0 CALIBRATION PROCEDURES

2.1 Analyzer Calibration Procedure

2.1.1 Each analyser shall be calibrated as often as necessary and in any case in the month before type approval testing and at least once every six months for verifying conformity of production.

2.1.2 Each normally used operating range shall be calibrated by the following procedure:

2.1.2.1 The analyser calibration curve is established by at least five calibration points spaced as uniformly as possibly. The nominal concentration of the calibration gas of the highest concentration shall be not less than 80% of the full scale.

2.1.2.2 The calibration gas concentration required may be obtained by means of a gas divider, diluting with purified N2 or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined to within ± 2%.

2.1.2.3 The calibration curve is calculated by the least squares method. If the resulting polynomial degree is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

2.1.2.4 The calibration curve shall not differ by more than ±2% from the nominal value of each calibration gas.

2.1.3 Trace of the calibration curve

From the trace of the calibration curve and the calibration points, it is possible to verify that the calibration has been carried out correctly. The different characteristic parameters of the analyser shall be indicated, particularly:

The scale;

The sensitivity;

The zero point;

The date of carrying out the calibration.

2.1.4 If it can be shown to the satisfaction of the Test Agency that alternative technology (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used.

2.2 Analyzer Verification Procedure

2.2.1 Each normally used operating range shall be checked prior to each analysis in accordance with the following:

2.2.2 The calibration shall be checked by use of a zero gas and by use of a span gas that has a nominal value within 80-95% of the supposed value to be analysed.

2.2.3 If, for the two points considered, the value found does not differ by more than ±5% of the full scale from the theoretical value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with clause 2.1 of this Chapter.

2.2.4 After testing, zero gas and the same span gas are used for re-checking. The analysis is considered acceptable if the difference between the two measuring results is less than 2%.

2.3 **FID Hydrocarbon Response Check Procedure**

2.3.1 Detector response optimization

The FID shall be adjusted, as specified by the instrument manufacturer. Propane in air should be used, to optimize the response, on the most common operating range.

2.3.2 Calibration of the HC analyzer

The analyzer should be calibrated using propane in air and purified synthetic air as indicated below in clause 3.0 of this Chapter.

Establish a calibration curve as described in clause 2.1. of this Chapter.

2.3.3 Response factors of different hydrocarbons and recommended limits

The response factor (Rf), for a particular hydrocarbon species is the ratio of the FID C_1 reading to the gas cylinder concentration, expressed as ppm C_1.

The concentration of the test gas shall be at a level to give a response of approximately 80% of full-scale deflection, for the operating range. The concentration shall be known, to an accuracy of ±2% in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder shall be pre- conditioned for 24 hours at a temperature between 293 K and 303 K (20 and 30 °C).

Response factors should be determined when introducing an analyser into service and thereafter at major service intervals. The test gases to be used and the recommended response factors are:

Methane and purified air:	$1.00 < Rf < 1.15$ or $1.00 < Rf < 1.05$ for NG/biomethane fueled vehicles
Propylene and purified air:	$0.90 < Rf < 1.00$
Toluene and purified air:	$0.90 < Rf < 1.00$

These are relative to a response factor (Rf) of 1.00 for propane and purified air.

2.3.4 Oxygen Interference Check and Recommended Limits

The response factor shall be determined as described in clause 2.3.3 of this Chapter. The test gas to be used and recommended response factor range is:

Propane and nitrogen: $0.95 < Rf < 1.05$

2.4 **NO_x Converter Efficiency Test Procedure**

The efficiency of the converter used for the conversion of NO_2 into NO is tested as follows:

Using the test set up as shown in Figure 2 of this Chapter and the procedure described below, the efficiency of converters can be tested by means of an ozonator.

2.4.1 Calibrate the analyser in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which shall amount to about 80% of the operating range and the NO_2 concentration of the gas mixture shall be less than 5% of the NO concentration). The NO_x analyser shall be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

2.4.2 Via a T-fitting, oxygen or synthetic air is added continuously to the span gas flow until the concentration indicated is about 10% less than the indicated calibration concentration given in clause 2.4.1 above. Record the indicated concentration (c). The ozonator is kept deactivated throughout this process.

2.4.3 The ozonator is now activated to generate enough ozone to bring the NO concentration down to 20% (minimum 10%) of the calibration concentration given in clause 2.4.1 of this Chapter. Record the indicated concentration (d).

2.4.4 The NO_x analyzer is then switched to the NO_x mode, which means that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. Record the indicated concentration (a).

2.4.5 The ozonator is now deactivated. The mixture of gases described in clause 2.4.2 of this Chapter passes through the converter into the detector. Record the indicated concentration (b).

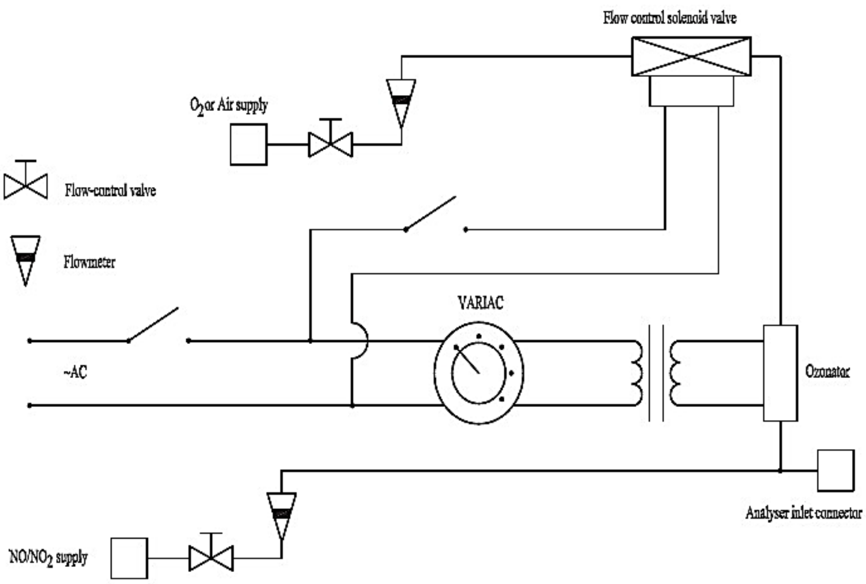


Figure 2

NOx Converter Efficiency Test Configuration

2.4.6 With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO_2 reading of the analyser shall then be no more than 5% above the figure given in clause 2.4.1 of this Chapter.

2.4.7 The efficiency of the NOx converter is calculated as follows:

$$\text{Efficiency} \quad (\text{per cent}) = \left(1 + \frac{a - b}{c - d}\right) \cdot 100$$

2.4.8 The efficiency of the converter shall not be less than 95%.

2.4.9 The efficiency of the converter shall be tested at least once a week.

3.0 REFERENCE GASES

3.1 Pure Gases

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

Purified nitrogen: (purity: $\leq$ 1 ppm C, $\leq$ 1 ppm CO, $\leq$ 400 ppm CO_2, $\leq$ 0.1 ppm NO);

Purified synthetic air: (purity: $\leq$ 1 ppm C, $\leq$ 1 ppm CO, $\leq$ 400 ppm CO_2, $\leq$ 0.1 ppm NO); oxygen content between 18 and 21% volume;

Purified oxygen: (purity > 99.5% vol. O_2);

Purified hydrogen (and mixture containing helium) : (purity $\leq$ 1 ppm C, $\leq$ 400 ppm CO_2);

Carbon monoxide: (minimum purity 99.5%);
Propane: (minimum purity 99.5%).
Propylene: (minimum purity 99.5%).

3.2 Calibration and Span Gases

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

(a) $C_3 H_8$ and purified synthetic air (see clause 3.1of this Chapter)
(b) CO and purified nitrogen;
(c) CO_2 and purified nitrogen.

NO and purified nitrogen (the amount of NO_2 contained in this calibration gas shall not exceed 5% of the NO content).

The true concentration of a calibration gas shall be within ±2% of the stated figure.

CHAPTER 8 - APPENDIX 1

PARTICULATE MASS EMISSIONS MEASUREMENT EQUIPMENT

1.0 SPECIFICATION

1.1 System Overview

1.1.1 The particulate sampling unit shall consist of a sampling probe located in the dilution tunnel, a particle transfer tube, a filter holder, a partial-flow pump, and flow rate regulators and measuring units.

1.1.2 It is recommended that a particle size pre-classifier (e.g. cyclone or impactor) be employed upstream of the filter holder. However, a sampling probe, acting as an appropriate size-classification device such as that shown in Figure 2 of this Appendix, is acceptable.

1.2 General Requirements

1.2.1 The sampling probe for the test gas flow for particulates shall be so arranged within the dilution tract that a representative sample gas flow can be taken from the homogeneous air/exhaust mixture.

1.2.2 The particulate sample flow rate shall be proportional to the total flow of diluted exhaust gas in the dilution tunnel to within a tolerance of ±5 % of the particulate sample flow rate.

1.2.3 The sampled dilute exhaust gas shall be maintained at a temperature below 325 K (52 °C) within 20 cm upstream or downstream of the particulate filter face, except in the case of a regeneration test where the temperature must be below 192 °C.

1.2.4 The particulate sample shall be collected on a single filter mounted within a holder in the sampled dilute exhaust gas flow.

1.2.5 All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, shall be designed to minimize deposition or alteration of the particulates. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

1.2.6 If it is not possible to compensate for variations in the flow rate, provision shall be made for a heat exchanger and a temperature control device as specified in clause 1.3.5 of Appendix 2 to Chapter 4 of this Part so as to ensure that the flow rate in the system is constant and the sampling rate accordingly proportional.

1.3 Specific Requirements

1.3.1 PM Sampling Probe

1.3.1.1 The sample probe shall deliver the particle-size classification performance described in clause 1.3.1.4. of this Appendix. It is recommended that this performance be achieved by the use of a sharp-edged, open-ended probe facing directly into the direction of flow plus a pre-classifier (cyclone impactor, etc.). An appropriate sampling probe, such as that indicated in Figure 2 of this Appendix may alternatively be used provided it achieves the pre-classification performance described in clause 1.3.1.4.

1.3.1.2 The sample probe shall be installed near the tunnel centerline, between 10 and 20 tunnel diameters downstream of the exhaust gas inlet to the tunnel and have an internal diameter of at least 12 mm.

If more than one simultaneous sample is drawn from a single sample probe, the flow drawn from that probe shall be split into identical sub flows to avoid sampling artefacts.

If multiple probes are used, each probe shall be sharp-edged, open-ended and facing directly into the direction of flow. Probes shall be equally spaced around the central longitudinal axis of the dilution tunnel, with the spacing between probes at least 5 cm.

1.3.1.3 The distance from the sampling tip to the filter mount shall be at least five probe diameters, but shall not exceed 1,020 mm.

1.3.1.4 The pre-classifier (e.g. cyclone, impactor, etc.) shall be located upstream of the filter holder assembly. The pre-classifier 50% cut point particle diameter shall be between 2.5 µm and 10 µm at the volumetric flow rate selected for sampling particulate mass emissions. The pre-classifier shall allow at least 99% of the mass concentration of 1 µm particles entering the pre-classifier to pass through the exit of the pre-classifier at the volumetric flow rate selected for sampling particulate mass emissions. However, a sampling probe, acting as an appropriate size-classification device, such as that shown in Figure 2 of this Appendix, is acceptable as an alternative to a separate pre-classifier.

1.3.2 **Sample Pump and Flow Meter**

1.3.2.1 The sample gas flow measurement unit shall consist of pumps, gas flow regulators and flow measuring units.

1.3.2.2 The temperature of the gas flow in the flow meter may not fluctuate by more than ±3 K, except during regeneration tests on vehicles equipped with periodically regenerating after treatment devices. In addition, the sample mass flow rate must remain proportional to the total flow of diluted exhaust gas to within a tolerance of ±5%of the particulate sample mass flow rate. Should the volume of flow change unacceptably as a result of excessive filter loading, the test shall be stopped. When it is repeated, the rate of flow shall be decreased.

1.3.3 **Filter and Filter Holder**

1.3.3.1 A valve shall be located downstream of the filter in the direction of flow. The valve shall be quick enough acting to open and close within 1 s of the start and end of test.

1.3.3.2 It is recommended that the mass collected on the 47 mm diameter filter (P_e) is ≥ 20 µg and that the filter loading should be maximized consistent with the requirements of clauses 1.2.3 and 1.3.3. of this Appendix.

1.3.3.3 For a given test the gas filter face velocity shall be set to a single value within the range 20 cm/s to 80 cm/s unless the dilution system is being operated with sampling flow proportional to CVS flow rate.

1.3.3.4 Flurocarbon coated glass fibre filters or fluorocarbon membrane filters are required. All filter types shall have a 0.3 µm DOP (di-octylphthalate) or PAO (poly-alpha-olefin) CS 68649-12-7 or CS 68037-01-4 collection efficiency of at least 99% at a gas filter face velocity of 5.33 cm/s measured according to one of the following standards:

(a) U.S.A. Department of Defense Test Method Standard, MIL-STD-282 method 102.8: DOP-Smoke Penetration of Aerosol-Filter Element

(b) U.S.A. Department of Defense Test Method Standard, MIL-STD-282 method 502.1.1: DOP-Smoke Penetration of Gas-Mask Canisters

(c) Institute of Environmental Sciences and Technology, IEST-RP-CC021: Testing HEPA and ULPA Filter Media.

1.3.3.5 The filter holder assembly shall be of a design that provides an even flow distribution across the filter stain area. The filter stain area shall be at least 1,075 mm^2.

1.3.4 **Filter Weighing Chamber and Balance**

1.3.4.1 The microgram balance used to determine the weight of a filter shall have a precision (standard deviation) of 2 µg and resolution of 1 µg or better.

It is recommended that the microbalance be checked at the start of each weighing session by weighing one reference weight of 50 mg. This weight shall be weighed three times and the average result recorded. If the average result of the weighing's is ±5 µg of the result from the previous weighing session then the weighing session and balance are considered valid.

The weighing chamber (or room) shall meet the following conditions during all filter conditioning and weighing operations:

Temperature maintained at 295 ±3 K (22 ±3 °C);

Relative humidity maintained at 45% ± 8%;

Dew point maintained at 9.5 °C ±3 °C.

It is recommended that temperature and humidity conditions are recorded along with sample and reference filter weights.

1.3.4.2 Buoyancy Correction

All filter weights shall be corrected for filter buoyancy in air.

The buoyancy correction depends on the density of the sample filter medium, the density of air, and the density of the calibration weight used to calibrate the balance. The density of the air is dependent on the pressure, temperature and humidity.

It is recommended that the temperature and dew point of the weighing environment are controlled to 22°C ±1°C and dew point of 9.5°C ±1°C respectively. However, the minimum requirements stated in clause 1.3.4.1. of this Appendix will also result in an acceptable correction for buoyancy effects. The correction for buoyancy shall be applied as follows:

$$m_{corr} = m_{uncorr} \cdot \left(1-\left(\left(\rho_{air}\right)/\left(\rho_{weight}\right)\right)\right)/\left(1-\left(\left(\rho_{air}\right)/\left(\rho_{media}\right)\right)\right)$$

Where

m_{corr} =	PM mass corrected for buoyancy
M_{uncorr} =	PM mass uncorrected for buoyancy
ρ_{air} =	Density of air in balance environment
ρ_{weight} =	Density of calibration weight used to span balance
ρ_{media} =	Density of PM sample medium (filter) according to the table below:

Filter Medium	ρ_{media}
Teflon coated glass fibre (e.g. TX40)	2,300 kg/m^3

ρ_{air} can be calculated as follows:

$$\rho_{air} = \frac{P_{abs} \cdot M_{mix}}{R \cdot T_{amb}}$$

Where:

P_{abs} = absolute pressure in balance environment,

M_{mix} = molar mass of air in balance environment (28.836 $gmol^{-1}$)

R =molar gas constant (8.314 $Jmol^{-1}K^{-1}$)

T_{amb} = absolute ambient temperature of balance environment.

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilization.

Limited deviations from weighing room temperature and humidity specifications will be allowed provided their total duration does not exceed 30 minutes in any one filter conditioning period. The weighing room should meet the required specifications prior to personal entrance into the weighing room. During the weighing operation no deviations from the specified conditions are permitted.

1.3.4.3 The effects of static electricity shall be nullified. This may be achieved by grounding the balance through placement upon an antistatic mat and neutralization of the particulate filters prior to weighing using a Polonium neutralizer or a device of similar effect. Alternatively nullification of static effects may be achieved through equalization of the static charge.

1.3.4.4 A test filter shall be removed from the chamber no earlier than an hour before the test begins.

1.4 Recommended System Description

Figure 1 of this Appendix is a schematic drawing of the recommended particulate sampling system. Since various configurations can produce equivalent results, exact conformance with this figure is not required. Additional components such as instruments, valves, solenoids, pumps and switches may be used to provide additional information and co-ordinate the functions of component systems. Further components that are not needed to maintain accuracy with other system configurations may be excluded if their exclusion is based upon good engineering judgment.

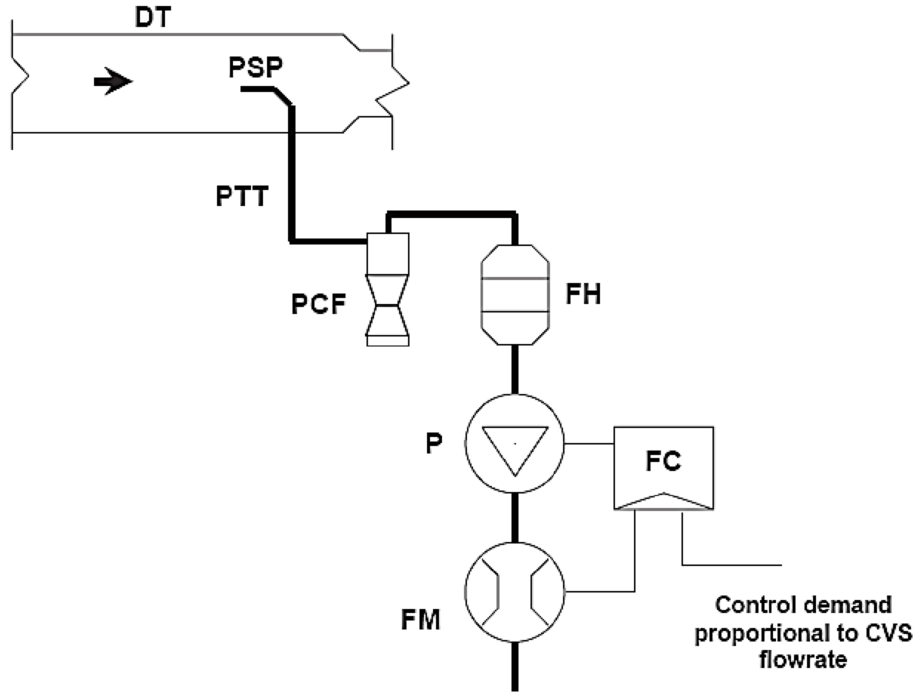


Figure 1

Particulate Sampling System

A sample of the diluted exhaust gas is taken from the full flow dilution tunnel DT through the particulate sampling probe PSP and the particulate transfer tube PTT by means of the pump P. The sample is passed through the particle size pre-classifier PCF and the filter holder(s) FH that contain the particulate sampling filter(s). The flow rate for sampling is set by the flow controller FC.

2.1 CALIBRATION AND VERIFICATION PROCEDURES

2.1 Flow Meter Calibration

The Test Agency shall ensure the existence of a calibration certificate for the flow meter demonstrating compliance with a traceable standard within a 12 month period prior to the test, or since any repair or change which could influence calibration.

2.2 Microbalance Calibration

The Test Agency shall ensure the existence of a calibration certificate for the microbalance demonstrating compliance with a traceable standard within a 12 months period prior to the test.

2.3 **Reference Filter Weighing**

To determine the specific reference filter weights, at least two unused reference filters shall be weighed within 8 hours of, but preferably at the same time as, the sample filter weighings. Reference filters shall be of the same size and material as the sample filter.

If the specific weight of any reference filter changes by more than ±5 µg between sample filter weighings, then the sample filter and reference filters shall be reconditioned in the weighing room and then reweighed.

The comparison of reference filter weighing's shall be made between the specific weights and the rolling average of that reference filter's specific weights.

The rolling average shall be calculated from the specific weights collected in the period since the reference filters were placed in the weighing room. The averaging period shall be at least 1 day but not exceed 30 days.

Multiple reconditioning and reweighing's of the sample and reference filters are permitted until a period of 80 h has elapsed following the measurement of gases from the emissions test.

If, prior to or at the 80 h point, more than half the number of reference filters meet the ±5µg criterion, then the sample filter weighing can be considered valid.

If, at the 80 h point, two reference filters are employed and one filter fails the ±5µg criterion, the sample filter weighing can be considered valid under the condition that the sum of the absolute differences between specific and rolling averages from the two reference filters must be less than or equal to 10 µg.

In case less than half of the reference filters meet the ±5 µg criterion the sample filter shall be discarded, and the emissions test repeated. All reference filters must be discarded and replaced within 48 hours.

In all other cases, reference filters must be replaced at least every 30 days and in such a manner that no sample filter is weighed without comparison to a reference filter that has been present in the weighing room for at least 1 day.

If the weighing room stability criteria outlined in clause 1.3.4. of this Appendix are not met, but the reference filter weighings meet the above criteria, the vehicle manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

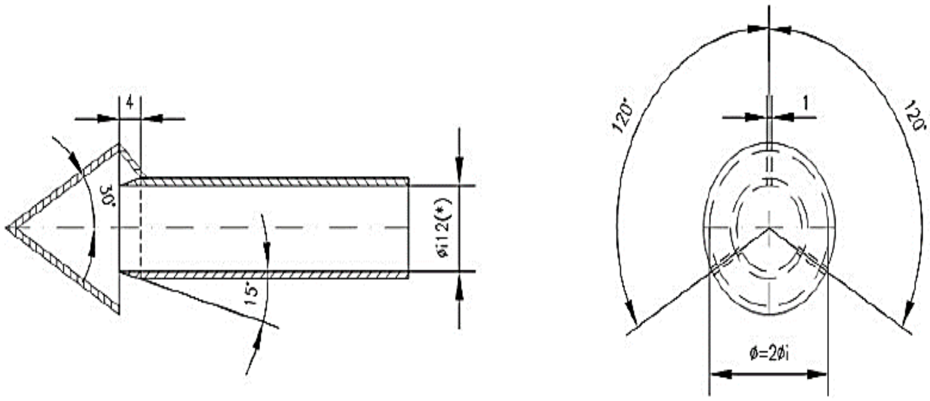


Figure 2

Particulate sampling probe configuration

(*) Minimum internal diameter

Wall thickness ~ 1 mm – Material: stainless steel

CHAPTER 8 - APPENDIX 2

PARTICLE NUMBER EMISSIONS MEASUREMENT EQUIPMENT

1.0 SPECIFICATION

1.1 System Overview

1.1.1 The particle sampling system shall consist of a dilution tunnel, a sampling probe and a Volatile Particle Remover (VPR) upstream of a Particle Number Counter (PNC) and suitable transfer tubing.

1.1.2 It is recommended that a particle size pre-classifier (e.g. cyclone, impactor etc.) be located prior to the inlet of the VPR. However, a sample probe acting as an appropriate size-classification device, such as that shown in Figure 2 of Appendix 1 of this Chapter, is an acceptable alternative to the use of a particle size pre-classifier.

1.2 General Requirements

1.2.1 The particle sampling point shall be located within a dilution tunnel.

The sampling probe tip or Particulate Sampling Point (PSP) and particle transfer tube (PTT) together comprise the Particle Transfer System (PTS). The PTS conducts the sample from the dilution tunnel to the entrance of the VPR. The PTS shall meet the following conditions:

It shall be installed near the tunnel centre line, 10 to 20 tunnel diameters downstream of the gas inlet, facing upstream into the tunnel gas flow with its axis at the tip parallel to that of the dilution tunnel.

It shall have an internal diameter of ≥ 8 mm.

Sample gas drawn through the PTS shall meet the following conditions: It shall have a flow Reynolds number (Re) of < 1,700;

It shall have a residence time in the PTS of ≤ 3 seconds.

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

The outlet tube (OT) conducting the diluted sample from the VPR to the inlet of the PNC shall have the following properties:

It shall have an internal diameter of ≥ 4 mm;

Sample Gas flow through the OT shall have a residence time of ≤ 0.8 seconds.

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

1.2.2 The VPR shall include devices for sample dilution and for volatile particle removal. The sampling probe for the test gas flow shall be so arranged within the dilution tract that a representative sample gas flow is taken from a homogeneous air/exhaust mixture.

1.2.3 All parts of the dilution system and the sampling system from the exhaust pipe up to the PNC, which are in contact with raw and diluted exhaust gas, shall be designed to minimize deposition of the particles. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

1.2.4 The particle sampling system shall incorporate good aerosol sampling practice that includes the avoidance of sharp bends and abrupt changes in cross-section, the use of smooth internal surfaces and the minimization of the length of the sampling line. Gradual changes in the cross-section are permissible.

1.3 Specific Requirements

1.3.1 The particle sample shall not pass through a pump before passing through the PNC.

1.3.2 A sample pre-classifier is recommended.

1.3.3 The sample preconditioning unit shall:

1.3.3.1 Be capable of diluting the sample in one or more stages to achieve a particle number concentration below the upper threshold of the single particle count mode of the PNC and a gas temperature below 35 °C at the inlet to the PNC;

1.3.3.2 Include an initial heated dilution stage which outputs a sample at a temperature of ≥ 150 °C and ≤ 400 °C and dilutes by a factor of at least 10;

1.3.3.3 Control heated stages to constant nominal operating temperatures, within the range specified in clause 1.3.3.2. above, to a tolerance of ±10 °C. Provide an indication of whether or not heated stages are at their correct operating temperatures.

1.3.3.4 Achieve a particle concentration reduction factor ($f_r(d_i)$), as defined in clause 2.2.2.of this Appendix, for particles of 30 nm and 50 nm electrical mobility diameters, that is no more than 30% and 20% respectively higher, and no more than 5% lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole;

1.3.3.5 Also achieve > 99.0% vaporization of 30 nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of ≥ 10,000 cm^{-3}, by means of heating and reduction of partial pressures of the tetracontane.

1.3.4 **The PNC shall:**

1.3.4.1 Operate under full flow operating conditions;

1.3.4.2 Have a counting accuracy of ±10% across the range 1 cm^{-3} to the upper threshold of the single particle count mode of the PNC against a traceable standard. At concentrations below 100 cm^{-3} measurements averaged over extended sampling periods may be required to demonstrate the accuracy of the PNC with a high degree of statistical confidence;

1.3.4.3 Have a readability of at least 0.1 particles cm^{-3} at concentrations below 100 cm^{-3}

1.3.4.4 Have a linear response to particle concentrations over the full measurement range in single particle count mode;

1.3.4.5 Have a data reporting frequency equal to or greater than 0.5 Hz;

1.3.4.6 Have a T90 response time over the measured concentration range of less than 5s;

1.3.4.7 Incorporate a coincidence correction function up to a maximum 10% correction, and may make use of an internal calibration factor as determined in clause 2.1.3.of this Appendix, but shall not make use of any other algorithm to correct for or define the counting efficiency;

1.3.4.8 Have counting efficiencies at particle sizes of 23 nm (±1 nm) and 41 nm (±1 nm) electrical mobility diameter of 50% (±12%) and >90% respectively. These counting efficiencies may be achieved by internal (for example; control of instrument design) or external (for example; size pre-classification) means;

1.3.4.9 If the PNC makes use of a working liquid, it shall be replaced at the frequency specified by the instrument manufacturer.

1.3.5 Where they are not held at a known constant level at the point at which PNC flow rate is controlled, the pressure and/or temperature at inlet to the PNC must be measured and reported for the purposes of correcting particle concentration measurements to standard conditions.

1.3.6 The sum of the residence time of the PTS, VPR and OT plus the T90 response time of the PNC shall be no greater than 20 s.

1.4 Recommended System Description

The following section contains the recommended practice for measurement of particle number. However, any system meeting the performance specifications in clauses 1.2 and 1.3 of this Appendix is acceptable.

Figure 1 of this Appendix is a schematic drawing of the recommended particle sampling system

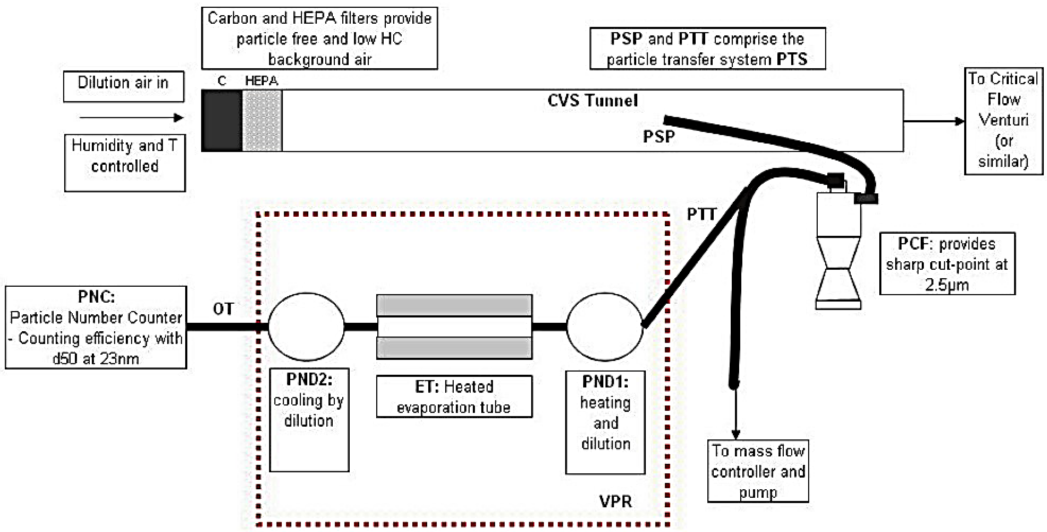


Figure 1

Schematic of Recommended Particle Sampling System

1.4.1 Sampling System Description

The particle sampling system shall consist of a sampling probe tip in the dilution tunnel (PSP), a Particle Transfer Tube (PTT), a Particle Pre-classifier (PCF) and a Volatile Particle Remover (VPR) upstream of the particle number concentration measurement (PNC) unit. The VPR shall include devices for sample dilution (particle number diluters: PND_1 and PND_2) and particle evaporation (Evaporation tube, ET). The sampling probe for the test gas flow shall be so arranged within the dilution tract that a representative sample gas flow is taken from a homogeneous air/exhaust mixture. The sum of the residence time of the system plus the T90 response time of the PNC shall be no greater than 20 s.

1.4.2 **Particle Transfer System**

The Particle Sampling Point (PSP) and particle transfer tube (PTT) together comprise the particle transfer system (PTS). The PTS conducts the sample from the dilution tunnel to the entrance to the first particle number diluter. The PTS shall meet the following conditions:

It shall be installed near the tunnel centre line, 10 to 20 tunnel diameters downstream of the gas inlet, facing upstream into the tunnel gas flow with its axis at the tip parallel to that of the dilution tunnel.

It shall have an internal diameter of ≥ 8 mm.

Sample gas drawn through the PTS shall meet the following conditions:

It shall have a flow Reynolds number (Re) of < 1700;

It shall have a residence time in the PTS of ≤ 3 seconds.

Any other sampling configuration for the PTS for which equivalent particle penetration for particles of 30 nm electrical mobility diameter can be demonstrated will be considered acceptable.

The Outlet Tube (OT) conducting the diluted sample from the VPR to the inlet of the PNC shall have the following properties:

It shall have an internal diameter of ≥ 4 mm;

Sample Gas flow through the POT shall have a residence time of ≤ 0.8 seconds.

Any other sampling configuration for the OT for which equivalent particle penetration for particles of 30 nm electrical mobility diameter can be demonstrated will be considered acceptable.

1.4.3 **Particle Pre-classifier**

The recommended particle pre-classifier shall be located upstream of the VPR. The pre-classifier 50% cut point particle diameter shall be between 2.5 µm and 10µm at the volumetric flow rate selected for sampling particle number emissions. The pre-classifier shall allow at least 99 % of the mass concentration of 1µm particles entering the pre-classifier to pass through the exit of the pre-classifier at the volumetric flow rate selected for sampling particle number emissions.

1.4.4 **Volatile Particle Remover (VPR)**

The VPR shall comprise one particle number diluter (PND_1), an evaporation tube and a second diluter (PND_2) in series. This dilution function is to reduce the number concentration of the sample entering the particle concentration measurement unit to less than the upper threshold of the single particle count mode of the PNC and to suppress nucleation within the sample. The VPR shall provide an indication of whether or not PND_1 and the evaporation tube are at their correct operating temperatures.

The VPR shall achieve > 99.0% vaporization of 30 nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of ≥ 10,000 cm^{-3}, by means of heating and reduction of partial pressures of the tetracontane. It shall also achieve a particle concentration reduction factor (f_r) for particles of 30 nm and 50 nm electrical mobility diameters, that is no more than 30% and 20% respectively higher, and no more than 5% lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole.

1.4.4.1 **First Particle Number Dilution Device (PND_1)**

The first particle number dilution device shall be specifically designed to dilute particle number concentration and operate at a (wall) temperature of 150°C – 400°C. The wall temperature set point should be held ata constant nominal operating temperature, within this range, to a tolerance of ±10 °C and not exceed the wall temperature of the ET (clause 1.4.4.2 of this Appendix). The diluter should be supplied with HEPA filtered dilution air and be capable of a dilution factor of 10 to 200 times. times.

1.4.4.2 **Evaporation Tube**

The entire length of the ET shall be controlled to a wall temperature greater than or equal to that of the first particle number dilution device and the wall temperature held at a fixed nominal operating temperature between 300°C and 400°C, to a tolerance of ±10°C.

1.4.4.3 **Second Particle Number Dilution Device (PND_2)**

PND_2 shall be specifically designed to dilute particle number concentration. The diluter shall be supplied with HEPA filtered dilution air and be capable of maintaining a single dilution factor within a range of 10 to 30 times. The dilution factor of PND_2 shall be selected in the range between 10 and 15 such that particle number concentration downstream of the second diluter is less than the upper threshold of the single particle count mode of the PNC and the gas temperature prior to entry to the PNC is < 35 °C.

1.4.5 Particle Number Counter (PNC)

The PNC shall meet the requirements of clause 1.3.4. of this Appendix.

2.0 CALIBRATION/VALIDATION OF THE PARTICLE SAMPLING SYSTEM

2.1 **Calibration of the Particle Number Counter**

2.1.1 The Test Agency shall ensure the existence of a calibration certificate for the PNC demonstrating compliance with a traceable standard within a 12 month period prior to the emissions test.

2.1.2 The PNC shall also be recalibrated and a new calibration certificate issued following any major maintenance.

2.1.3 Calibration shall be traceable to a standard calibration method:

(a) By comparison of the response of the PNC under calibration with that of a calibrated aerosol electrometer when simultaneously sampling electrostatically classified calibration particles; or

(b) By comparison of the response of the PNC under calibration with that of a second PNC which has been directly calibrated by the above method.

In the electrometer case, calibration shall be undertaken using at least six standard concentrations spaced as uniformly as possible across the PNC's measurement range. These points will include a nominal zero concentration point produced by attaching HEPA filters of at least class H13 of EN 1822:2008, or equivalent performance, to the inlet of each instrument. With no calibration factor applied to the PNC under calibration, measured concentrations shall be within ±10% of the standard concentration for each concentration used, with the exception of the zero point, otherwise the PNC under calibration shall be rejected. The gradient from a linear regression of the two data sets shall be calculated and recorded. A calibration factor equal to the reciprocal of the gradient shall be applied to the PNC under calibration. Linearity of response is calculated as the square of the Pearson product moment correlation coefficient (R^2) of the two data sets and shall be equal to or greater than 0.97. In calculating both the gradient and R^2 the linear regression shall be forced through the origin (zero concentration on both instruments).

In the reference PNC case, calibration shall be undertaken using at least six standard concentrations across the PNC's measurement range. At least three points shall be at concentrations below 1,000cm^{-3}, the remaining concentrations shall be linearly spaced between 1,000 cm^{-3} and the maximum of the PNC's range in single particle count mode. These points will include a nominal zero concentration point produced by attaching HEPA filters of at least class H13 of EN 1822:2008, or equivalent performance, to the inlet of each instrument. With no calibration factor applied to the PNC under calibration, measured concentrations shall be within ±10% of the standard concentration for each concentration, with the exception of the zero point, otherwise the PNC under calibration shall be rejected. The gradient from a linear regression of the two data sets shall be calculated and recorded. A calibration factor equal to the reciprocal of the gradient shall be applied to the PNC under calibration. Linearity of response is calculated as the square of the Pearson product moment correlation coefficient (R^2) of the two data sets and shall be equal to or greater than 0.97. In calculating both the gradient and R^2 the linear regression shall be forced through the origin (zero concentration on both instruments).

2.1.4 Calibration shall also include a check, against the requirements in clause 1.3.4.8.of this Appendix, on the PNC's detection efficiency with particles of 23 nm electrical mobility diameter. A check of the counting efficiency with 41 nm particles is not required.

2.2 Calibration/Validation of the Volatile Particle Remover

2.2.1 Calibration of the VPR's particle concentration reduction factors across its full range of dilution settings, at the instrument's fixed nominal operating temperatures, shall be required when the unit is new and following any major maintenance. The periodic validation requirement for the VPR's particle concentration reduction factor is limited to a check at a single setting, typical of that used for measurement on diesel particulate filter equipped vehicles.

The Test Agency shall ensure the existence of a calibration or validation certificate for the volatile particle remover within a 6 month period prior to the emissions test. If the volatile particle remover incorporates temperature monitoring alarms a 12 month validation interval shall be permissible. The VPR shall be characterized for particle concentration reduction factor with solid particles of 30 nm, 50 nm and 100 nm electrical mobility diameter. Particle concentration reduction factors ($f_r(d)$) for particles of 30 nm and 50 nm electrical mobility diameters shall be no more than 30% and 20% higher respectively, and no more than 5% lower than that for particles of 100 nm electrical mobility diameter. For The purposes of validation, the mean particle concentration reduction factor shall be within ± 10% of the mean particle concentration reduction factor ($\bar{f_r}$) determined during the primary calibration of the VPR.

2.2.2 The test aerosol for these measurements shall be solid particles of 30, 50 and 100 nm electrical mobility diameter and a minimum concentration of 5,000 cm^{-3} particles at the VPR inlet. Particle concentrations shall be measured upstream and downstream of the components.

The particle concentration reduction factor at each particle size ($f_r(d_i)$) shall be calculated as follows;

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)}$$

Where:

$N_{in}(d_i)$ = upstream particulate number concentration for particulates of diameter di;

$N_{out}(d_i)$ = downstream particulate number concentration for particulates of diameter di; and

d_i = particulate electrical mobility diameter (30, 50 or 100 nm).

Nin(di) and Nout(di) shall be corrected to the same conditions.

The mean particle concentration reduction $\overline{f_r}$ at a given dilution setting shall be calculated as follows;

$$\overline{f_r} = \frac{f_r(30nm) + f_r(50nm) + f_r(100nm)}{3}$$

It is recommended that the VPR is calibrated and validated as a complete unit

2.2.3 The Test Agency shall ensure the existence of a validation certificate for the VPR demonstrating effective volatile particle removal efficiency within a 6 month period prior to the emissions test. If the volatile particle remover incorporates temperature monitoring alarms a 12month validation interval shall be permissible. The VPR shall demonstrate greater than 99.0% removal of tetracontane ($CH_3(CH_2)_{38}CH_3$) particles of at least 30 nm electrical mobility diameter with an inlet concentration of $\geq$ 10,000 cm^{-3} when operated at its minimum dilution setting and manufacturers recommended operating temperature.

2.3 Particle Number System Check Procedures

2.3.1 Prior to each test, the particle counter shall report a measured concentration of less than 0.5 particles cm-3 when a HEPA filter of at least class H13 of EN 1822:2008, or equivalent performance, is attached to the inlet of the entire particle sampling system (VPR and PNC).

2.3.2 On a monthly basis, the flow into the particle counter shall report a measured value within 5% of the particle counter nominal flow rate when checked with a calibrated flow meter.

2.3.3 Each day, following the application of a HEPA filter of at least class H13 of EN 1822:2008, or equivalent performance, to the inlet of the particle counter, the particle counter shall report a concentration of $\leq$ 0.2cm-3. Upon removal of this filter, the particle counter shall show an increase in measured concentration to at least 100 particles cm-3 when challenged with ambient air and a return to $\leq$ 0.2 cm-3 on replacement of the HEPA filter.

2.3.4 Prior to the start of each test, it shall be confirmed that the measurement system indicates that the evaporation tube, where featured in the system, has reached its correct operating temperature.

2.3.5 Prior to the start of each test, it shall be confirmed that the measurement system indicates that the diluter PND_1 has reached its correct operating temperature.

CHAPTER 9

TYPE II TEST AND FREE ACCELERATION SMOKE TEST

1.0 INTRODUCTION

This Chapter describes the procedure for the Type II test defined in clause 5.3.2 of Chapter 1 of this Part and free acceleration smoke measurement applicable for compression ignition Engines only.

2.0 CONDITIONS OF MEASUREMENT FOR IDLE SPEED

2.1 The fuel shall be the appropriate reference fuel.

2.2 During the test, the environmental temperature shall be between 293 and 303 K (20 and 30°C). The engine shall be warmed up until all temperatures of cooling and lubrication means and the pressure of lubrication means have reached equilibrium.

2.2.1 Vehicles that are fuelled either with gasoline or with LPG or NG/biomethane shall be tested with the reference fuel(s) used for the Type I Test.

2.3 In the case of vehicles with manually-operated or semi-automatic-shift gearboxes, the test shall be carried out with the gear lever in the "neutral" position and with the clutch engaged.

2.4 In the case of vehicles with automatic-shift gearboxes, the test shall be carried out with the gear selector in either the "neutral" or the "parking" position.

2.5 Components for Adjusting the Idling Speed

2.5.1 Definition

For the purposes of this Part, "components for adjusting the idling speed" means controls for changing the idling conditions of the engine which may be easily operated by a mechanic using only the tools described in clause 2.5.1.1 of this Chapter. In particular, devices for calibrating fuel and air flows are not considered as adjustment components if their setting requires the removal of the set-stops, an operation which cannot normally be performed except by a professional mechanic.

2.5.1.1 Tools which may be used to control components for adjusting the idling speed: screwdrivers (ordinary or cross-headed), spanners (ring, open-end or adjustable), pliers, allen keys.

2.5.2 **Determination of Measurement Points**

2.5.2.1 A measurement at the setting in accordance with the conditions fixed by the manufacturer is performed first;

2.5.2.2 For each adjustment component with a continuous variation, a sufficient number of characteristic positions shall be determined.

2.5.2.3 The measurement of the gaseous pollutant of exhaust gases described in Gazette Notification shall be carried out for all the possible positions of the adjustment components, but for components with a continuous variation only the positions defined in clause 2.5.2.2 of this Chapter shall be adopted.

2.5.2.4 The Type II Test shall be considered satisfactory if one or both of the two following conditions is met:

2.5.2.4.1 None of the values measured in accordance with clause 2.5.2.3 of this Chapter exceeds the limit values;

2.5.2.4.2 The maximum content obtained by continuously varying one of the adjustment components while the other components are kept stable does not exceed the limit value, this condition being met for the various combinations of adjustment components other than the one which was varied continuously.

2.5.2.5 The possible positions of the adjustment components shall be limited:

2.5.2.5.1 On the one hand, by the larger of the following two values: the lowest idling speed which the engine can reach; the speed recommended by the manufacturer, minus 100 revolutions per minute;

2.5.2.5.2 On the other hand, by the smallest of the following three values:

The highest speed the engine can attain by activation of the idling speed components;

The speed recommended by the manufacturer, plus 250 revolutions per minute;

The cut-in speed of automatic clutches.

2.5.2.5.6 In addition, settings incompatible with correct running of the engine shall not be adopted as measurement settings. In particular, when the engine is equipped with several carburettors all the carburettors shall have the same setting.

3.0 SAMPLING OF GASES

3.1 The sampling probe shall be inserted into the exhaust pipe to a depth of at least 300 mm into the pipe connecting the exhaust with the sampling bag and as close as possible to the exhaust.

3.2 The concentration in CO (C_{CO}) and CO_2 (C_{CO2}) shall be determined from the measuring instrument readings or recordings by use of appropriate calibration curves.

3.3 The corrected concentration for carbon monoxide regarding four-stroke engines is:

$$C_{CO\,corr} = C_{CO} \frac{15}{C_{CO} + C_{CO2}} \qquad \text{(per cent vol.)}$$

3.4 The concentration in C_{CO} (see clause 3.2.of this Chapter) measured according to the formula contained in clause 3.3. of this Chapter, need not be corrected if the total of the concentrations measured (C_{CO} + C_{CO2}) is for four-stroke engines at least:

(a) For gasoline 15%

(b) For LPG 13.5%

(c) For NG/biomethane 11.5%

4.0 FREE ACCELERATION SMOKE TEST

4.1 This test is applicable for vehicles equipped with compression-ignition engines only.

4.2 The free acceleration smoke test shall be considered satisfactory if the values measured in accordance with Appendix 6 of Chapter 1 of AIS-137 (Part 5) meets limit values defined in Gazette Notification.

CHAPTER 10

TYPE III TEST
VERIFYING EMISSIONS OF CRANKCASE GASES

1.0 INTRODUCTION

This Chapter describes the procedure for the Type III Test.

2.0 GENERAL PROVISIONS

2.1 The Type III Test shall be carried out on a vehicle with positive-ignition engine, which has been, subjected to the Type I and the Type II Test, as applicable.

2.2 The engines tested shall include leak-proof engines other than those so designed that even a slight leak may cause unacceptable operating faults (such as flat-twin engines).

3.0 TEST CONDITIONS

3.1 Idling shall be regulated in conformity with the manufacturer's recommendations.

3.2 The measurement shall be performed in the following three sets of conditions of engine operation:

Condition Number	Vehicle speed (km/h)
1	Idling
2	50 ±2 (in 3rd gear or "drive")
3	50 ±2 (in 3rd gear or "drive")

Condition Number	Power absorbed by the brake
1	Nil
2	That corresponding to the setting for Type I test at 50 km/h
3	That for conditions No. 2, multiplied by a factor of 1.7

4.0 TEST METHOD

4.1 For the operation conditions as listed in clause 3.2 of this Chapter, reliable function of the crankcase ventilation system shall be checked.

5.0 METHOD OF VERIFICATION OF THE CRANKCASE VENTILATION SYSTEM

5.1 The engine's apertures shall be left as found.

5.2 The pressure in the crankcase shall be measured at an appropriate location. It shall be measured at the dip-stick hole with an inclined-tube manometer.

5.3 The vehicle shall be deemed satisfactory if, in every condition of measurement defined in clause 3.2 of this Chapter, the pressure measured in the crankcase does not exceed the atmospheric pressure prevailing at the time of measurement.

5.4 For the test by the method described above, the pressure in the intake manifold shall be measured to within ±1 kPa.

5.5 The vehicle speed as indicated at the dynamometer shall be measured to within ±2 km/ h.

5.6 The pressure measured in the crankcase shall be measured to within ±0.01 kPa.

5.7 If in one of the conditions of measurement defined in clause 3.2 of this Chapter, the pressure measured in the crankcase exceeds the atmospheric pressure, an additional test as defined in clause 6 below shall be performed if so requested by the manufacturer.

6.0 ADDITIONAL TEST METHOD

6.1 The engine's apertures shall be left as found.

6.2 A flexible bag impervious to crankcase gases and having a capacity of approximately five litres shall be connected to the dipstick hole. The bag shall be empty before each measurement.

6.3 The bag shall be closed before each measurement. It shall be opened to the crankcase for 5 minutes for each condition of measurement prescribed in clause 3.2 of this Chapter.

6.4 The vehicle shall be deemed satisfactory if, in every condition of measurement defined in clause 3.2 of this Chapter, no visible inflation of the bag occurs.

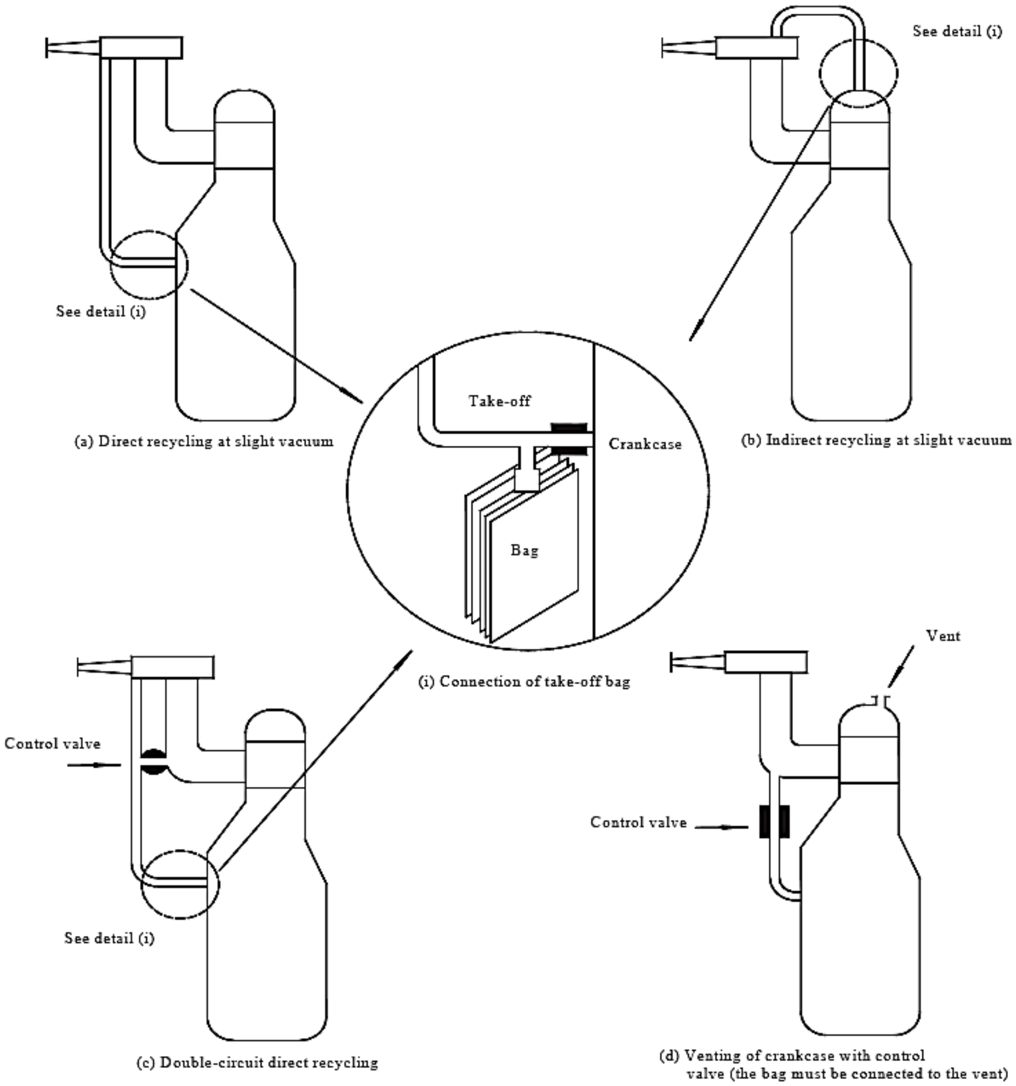
6.5 **Remark**

6.5.1 If the structural layout of the engine is such that the test cannot be performed by the methods described in clauses 6.1 to 6.4 of this Chapter, the measurements shall be effected by that method modified as follows:

6.5.2 Before the test, all apertures other than that required for the recovery of the gases shall be closed;

6.5.3 The bag shall be placed on a suitable take-off which does not introduce any additional loss of pressure and is installed on the recycling circuit of the device directly at the engine-connection aperture (See diagram below).

Type III Test



CHAPTER 11

TYPE IV TEST

DETERMINATION OF EVAPORATIVE EMISSIONS FROM VEHICLES WITH POSITIVE- IGNITION ENGINES

1.0 INTRODUCTION

This Chapter describes the procedure of the Type IV Test

This procedure describes a method for the determination of the loss of hydrocarbons by evaporation from the fuel systems of vehicles with positive ignition engines.

2.0 DESCRIPTION OF TEST

The evaporative emissions test (see Figure 1 of this Chapter) is designed to determine hydrocarbon evaporative emissions as a consequence of diurnal temperatures fluctuation, hot soaks during parking, and urban driving. The test consists of these phases:

2.1 Test preparation including an urban (Part One) and extra-urban (Part Two) driving cycle,

2.2 Hot soak loss determination,

Diurnal loss determination.

Mass emissions of hydrocarbons from the hot soak and the diurnal loss phases are added up to provide an overall result for the test.

3.0 VEHICLE AND FUEL

3.1 Vehicle

3.1.1 The vehicle shall be in good mechanical condition and have been run in and driven at least 3,000 km before the test. The evaporative emission control system shall be connected and have been functioning correctly over this period and the carbon canister(s) shall have been subject to normal use, neither undergoing abnormal purging nor abnormal loading.

3.2 **Fuel**

3.2.1 The appropriate reference fuel as prescribed in the applicable Gazette Notification under CMVR shall be used.

4.0 TEST EQUIPMENT FOR EVAPORATIVE TEST

4.1 **Chassis Dynamometer**

The chassis dynamometer shall meet the requirements of the one used for Type I Test.

4.2 **Evaporative Emission Measurement Enclosure**

The evaporative emission measurement enclosure shall be a gas-tight rectangular measuring chamber able to contain the vehicle under test. The vehicle shall be accessible from all sides and the enclosure when sealed shall be gas-tight in accordance with the Chapter 6 of this Part.

The inner surface of the enclosure shall be impermeable and non-reactive to hydrocarbons. The temperature conditioning system shall be capable of controlling the internal enclosure air temperature to follow the prescribed temperature versus time profile throughout the test, and an average tolerance of 1 K over the duration of the test.

The control system shall be tuned to provide a smooth temperature pattern that has a minimum of overshoot, hunting, and instability about the desired long-term ambient temperature profile. Interior surface temperatures shall not be less than 278 K (5 °C) nor more than 328 K (55°C) at any time during the diurnal emission test.

Wall design shall be such as to promote good dissipation of heat. Interior surface temperatures shall not be below 293 K (20°C), nor above 325 K (52 °C) for the duration of the hot soak rest.

To accommodate the volume changes due to enclosure temperature changes, either a variable-volume or fixed-volume enclosure may be used.

4.2.1 **Variable-Volume Enclosure**

The variable-volume enclosure expands and contracts in response to the temperature change of the air mass in the enclosure. Two potential means of accommodating the internal volume changes are movable panel(s), or a bellows design, in which an impermeable bag or bags inside the enclosure expand(s) and contracts(s) in response to internal pressure changes by exchanging air from outside the enclosure. Any design for volume accommodation shall maintain the integrity of the enclosure as specified in Chapter 6 over the specified temperature range.

Any method of volume accommodation shall limit the differential between the enclosure internal pressure and the barometric pressure to a maximum value of ±5 kPa.

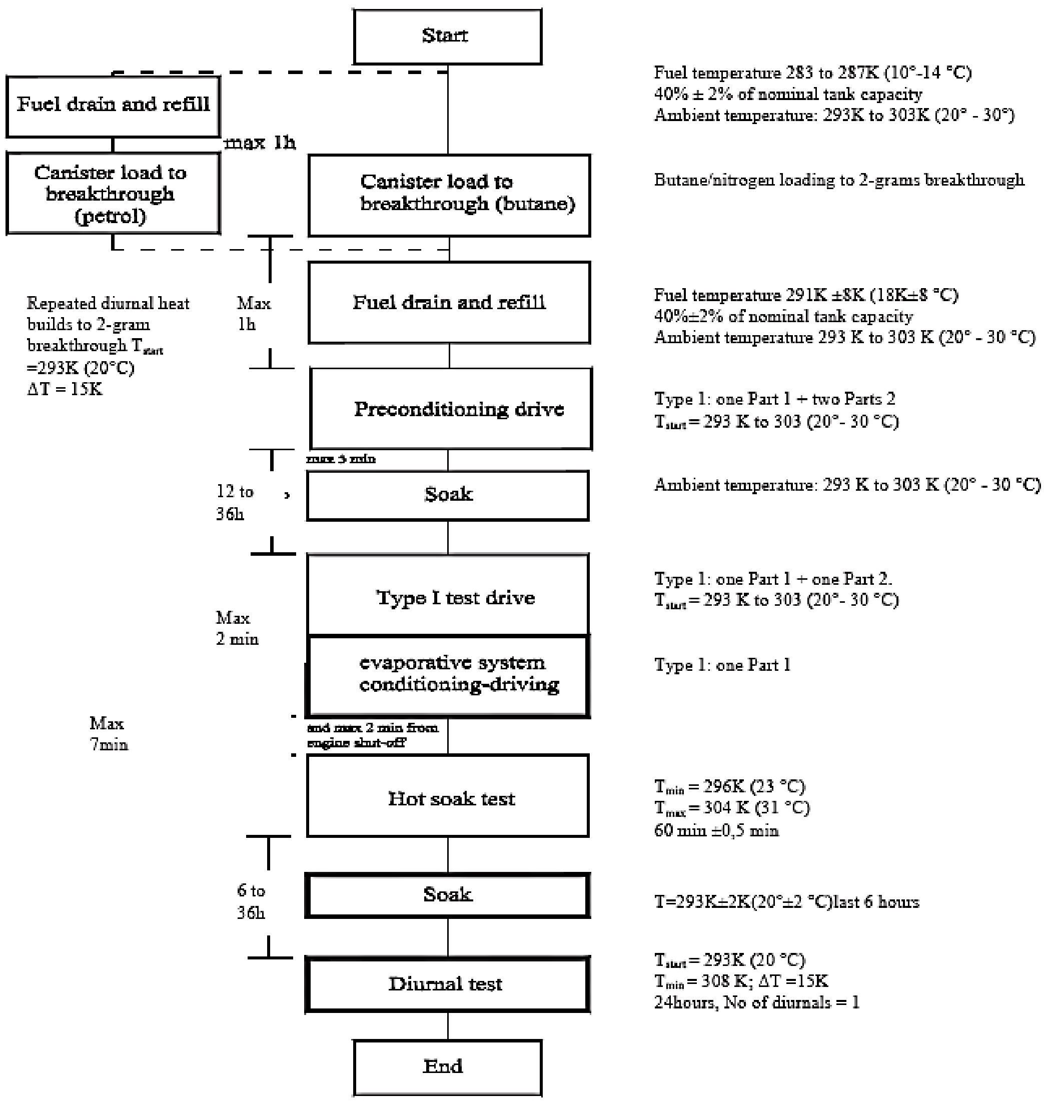
The enclosure shall be capable of latching to a fixed volume. A variable volume enclosure shall be capable of accommodating a +7 % change from its "nominal volume" (see clause 2.1.1 of Chapter 6 of this Part), taking into account temperature and barometric pressure variation during testing.

4.2.2 **Fixed-Volume Enclosure**

The fixed-volume enclosure shall be constructed with rigid panels that maintain a fixed enclosure volume, and meet the requirements below.

4.2.2.1 The enclosure shall be equipped with an outlet flow stream that withdraws air at a low, constant rate from the enclosure throughout the test. An inlet flow stream may provide make-up air to balance the outgoing flow with incoming ambient air. Inlet air shall be filtered with activated carbon to provide a relatively constant hydrocarbon level. Any method of volume accommodation shall maintain the differential between the enclosure internal pressure and the barometric pressure between 0 and -5 kPa.

4.2.2.2 The equipment shall be capable of measuring the mass of hydrocarbon in the inlet and outlet flow streams with a resolution of 0.01 gram. A bag sampling system may be used to collect a proportional sample of the air withdrawn from and admitted to the enclosure. Alternatively, the inlet and outlet flow streams may be continuously analyzed using an on-line FID analyzer and integrated with the flow measurements to provide a continuous record of the mass hydrocarbon removal.



Notes:

1. Evaporative emission control families - details clarified.
2. Exhaust emissions may be measured during Type I test drive but these are not used for legislative purposes. Exhaust emission legislative test remains separate.

Figure 1
Determination of Evaporative Emissions 3000 Km Run-in Period (No Excessive Purge/Load) Ageing of Canister(S) Verified Steam-Clean of Vehicle (If necessary)

4.3 Analytical Systems

4.3.1 **Hydrocarbon Analyzer**

4.3.1.1 The atmosphere within the chamber is monitored using a hydrocarbon detector of the flame ionization detector (FID) type. Sample gas shall be drawn from the mid-point of one side wall or roof of the chamber and any bypass flow shall be returned to the enclosure, preferably to a point immediately downstream of the mixing fan.

4.3.1.2 The hydrocarbon analyzer shall have a response time to 90 % of final reading of less than 1.5 seconds. Its stability shall be better than 2% of full scale at zero and at 80 ±20% of full scale over a 15-minute period for all operational ranges.

4.3.1.3 The repeatability of the analyzer expressed as one standard deviation shall be better than ±1% of full scale deflection at zero and at 80 ±20% of full scale on all ranges used.

4.3.1.4 The operational ranges of the analyzer shall be chosen to give best resolution over the measurement, calibration and leak checking procedures.

4.3.2 **Hydrocarbon Analyzer Data Recording System**

4.3.2.1 The hydrocarbon analyzer shall be fitted with a device to record electrical signal output either by strip chart recorder or other data processing system at a frequency of at least once per minute. The recording system shall have operating characteristics at least equivalent to the signal being recorded and shall provide a permanent record of results. The record shall show a positive indication of the beginning and end of the hot soak or diurnal emission test (including beginning and end of sampling periods along with the time elapsed between start and completion of each test).

4.4 Fuel Tank Heating (only applicable for gasoline canister load option)

4.4.1 The fuel in the vehicle tank(s) shall be heated by a controllable source of heat; for example a heating pad of 2,000 W capacity is suitable. The heating system shall apply heat evenly to the tank walls beneath the level of the fuel so as not to cause local overheating of the fuel. Heat shall not be applied to the vapour in the tank above the fuel.

4.4.2 The tank heating device shall make it possible to heat the fuel in the tank evenly by 14 K from 289 K (16°C) within 60 minutes, with the temperature sensor position as in clause 5.1.1 of this Chapter. The heating system shall be capable of controlling the fuel temperature to ±1.5 K of the required temperature during the tank heating process.

4.5 Temperature Recording

4.5.1 The temperature in the chamber is recorded at two points by temperature sensors which are connected so as to show a mean value. The measuring points are extended approximately 0.1 m into the enclosure from the vertical centre line of each side wall at a height of 0.9 ±0.2 m.

4.5.2 The temperatures of the fuel tank(s) are recorded by means of the sensor positioned in the fuel tank as in clause 5.1.1 of this Chapter in the case of use of the gasoline canister load option (clause 5.1.5 of this Chapter).

4.5.3 Temperatures shall, throughout the evaporative emission measurements, be recorded or entered into a data processing system at a frequency of at least once per minute.

4.5.4 The accuracy of the temperature recording system shall be within ±1.0 K and the temperature shall be capable of being resolved to ±0.4 K.

4.5.5 The recording or data processing system shall be capable of resolving time to ±15 seconds.

4.6 Pressure Recording

4.6.1 The difference Δp between barometric pressure within the test area and the enclosure internal pressure shall, throughout the evaporative emission measurements, be recorded or entered into a data processing system at a frequency of at least once per minute.

4.6.2 The accuracy of the pressure recording system shall be within ±2 kPa and the pressure shall be capable of being resolved to ±0.2 kPa.

4.6.3 The recording or data processing system shall be capable of resolving time to ±15 seconds.

4.7 Fans

4.7.1 By the use of one or more fans or blowers with the Sealed Housing Evaporating Determination (SHED) door(s) open it shall be possible to reduce the hydrocarbons concentration in the chamber to the ambient hydrocarbon level.

4.7.2 The chamber shall have one or more fans or blowers of like capacity 0.1 to 0.5 m^3/min. with which to thoroughly mix the atmosphere in the enclosure. It shall be possible to attain an even temperature and hydrocarbon concentration in the chamber during measurements. The vehicle in the enclosure shall not be subjected to a direct stream of air from the fans or blowers.

4.8 Gases

4.8.1 The following pure gases shall be available for calibration and operation:

Purified synthetic air: (purity < 1 ppm C_1 equivalent, ≤1 ppm CO, ≤ 400 ppm CO_2, ≤0.1 ppm NO);

Oxygen content between 18 and 21% by volume.

Hydrocarbon analyzer fuel gas: (40 ±2% hydrogen, and balance helium with less than 1 ppm C_1 equivalent hydrocarbon, less than 400 ppm CO_2),

Propane (C_3H_8)	99.5 %minimum purity.
Butane (C_4H_{10})	98 % minimum purity.
Nitrogen (N_2)	98 %minimum purity

4.8.2 Calibration and span gases shall be available containing mixtures of propane (C_3H_8) and purified synthetic air. The true concentrations of a calibration gas shall be within 2% of the stated figures. The accuracy of the diluted gases obtained when using a gas divider shall be to within ±2% of the true value. The concentrations specified in Chapter 6 of this part may also be obtained by the use of a gas divider using synthetic air as the dilutant gas.

4.9 Additional Equipment

4.9.1 The absolute humidity in the test area shall be measurable to within ±5%

5.0. TEST PROCEDURE

5.1 Test Preparation

5.1.1 The vehicle is mechanically prepared before the test as follows:

(a) The exhaust system of the vehicle shall not exhibit any leaks;

(b) The vehicle may be steam-cleaned before the test;

(c) In the case of use of the gasoline canister load option (clause 5.1.5. of this Chapter) the fuel tank of the vehicle shall be equipped with a temperature sensor to enable the temperature to be measured at the mid-point of the fuel in the fuel tank when filled to 40% of its capacity;

(d) Additional fittings, adapters of devices may be fitted to the fuel system in order to allow a complete draining of the fuel tank. For this purpose it is not necessary to modify the shell of the tank;

(e) The manufacturer may propose a test method in order to take into account the loss of hydrocarbons by evaporation coming only from the fuel system of the vehicle.

The vehicle is taken into the test area where the ambient temperature is between 293 and 303 K (20 and 30 °C).

5.1.3 The ageing of the canister(s) has to be verified. This may be done by demonstrating that it has accumulated a minimum of 3,000 km. If this demonstration is not given, the following procedure is used. In the case of a multiple canister system each canister shall undergo the procedure separately.

5.1.3.1 The canister is removed from the vehicle. Special care shall be taken during this step to avoid damage to components and the integrity of the fuel system.

5.1.3.2 The weight of the canister shall be checked.

5.1.3.3 The canister is connected to a fuel tank, possibly an external one, filled with reference fuel, to 40% volume of the fuel tank(s).

5.1.3.4 The fuel temperature in the fuel tank shall be between 183 K and 287 K (10 and 14 °C).

5.1.3.5 The (external) fuel tank is heated from 288 K to 318 K (15 to 45 °C) (1 °C increase every 9 minutes).

5.1.3.6 If the canister reaches breakthrough before the temperature reaches 318 K (45 °C), the heat source shall be turned off. Then the canister is weighed. If the canister did not reach breakthrough during the heating to 318 K (45 °C), the procedure from clause 5.1.3.3 of this Chapter shall be repeated until breakthrough occurs.

5.1.3.7 Breakthrough may be checked as described in clauses 5.1.5. and 5.1.6 of this Chapter, or with the use of another sampling and analytical arrangement capable of detecting the emission of hydrocarbons from the canister at breakthrough.

5.1.3.8 The canister shall be purged with 25 ±5 litres per minute with the emission laboratory air until 300 bed volume exchanges are reached.

5.1.3.9 The weight of the canister shall be checked.

5.1.3.10 The steps of the procedure in clauses 5.1.3.4 to 5.1.3.9 of this Chapter shall be repeated nine times. The test may be terminated prior to that, after not less than three ageing cycles, if the weight of the canister after the last cycles has stabilized.

5.1.3.11 The evaporative emission canister is reconnected and the vehicle restored to its normal operating condition.

5.1.4 One of the methods specified in clauses 5.1.5 and 5.1.6 of this Chapter shall be used to precondition the evaporative canister. For vehicles with multiple canisters, each canister shall be preconditioned separately.

5.1.4.1 Canister emissions are measured to determine breakthrough.

Breakthrough is here defined as the point at which the cumulative quantity of hydrocarbons emitted is equal to 2 grams.

5.1.4.2 Breakthrough may be verified using the evaporative emission enclosure as described in clauses 5.1.5 and 5.1.6 respectively. Alternatively, breakthrough may be determined using an auxiliary evaporative canister connected downstream of the vehicle's canister. The auxiliary canister shall be well purged with dry air prior to loading.

5.1.4.3 The measuring chamber shall be purged for several minutes immediately before the test until a stable background is obtained. The chamber air mixing fan(s) shall be switched on at this time.

The hydrocarbon analyzer shall be zeroed and spanned immediately before the test

5.1.5 Canister loading with repeated heat builds to breakthrough

5.1.5.1 The fuel tank(s) of the vehicle(s) is (are) emptied using the fuel tank drain(s). This shall be done so as not to abnormally purge or abnormally load the evaporative control devices fitted to the vehicle. Removal of the fuel cap is normally sufficient to achieve this.

5.1.5.2 The fuel tank(s) is (are) refilled with test fuel at a temperature of between 283 K to 287 K (10 to 14°C) to 40 ±2% of the tank's normal volumetric capacity. The fuel cap(s) of the vehicle shall be fitted at this point.

5.1.5.3 Within one hour of being re-fuelled the vehicle shall be placed, with the engine shut off, in the evaporative emission enclosure. The fuel tank temperature sensor is connected to the temperature recording system. A heat source shall be properly positioned with respect to the fuel tank(s) and connected to the temperature controller. The heat source is specified in clause 4.4 of this Chapter. In the case of vehicles fitted with more than one fuel tank, all the tanks shall be heated in the same way as described below. The temperatures of the tanks shall be identical to within ±1.5 K.

5.1.5.4 The fuel may be artificially heated to the starting diurnal temperature of 293 K (20 °C) ±1 K.

5.1.5.5 When the fuel temperature reaches at least 292 K (19 °C), the following steps shall be taken immediately: the purge blower shall be turned off; enclosure doors closed and sealed; and measurement initiated of the hydrocarbon level in the enclosure.

5.1.5.6 When the fuel temperature of the fuel tank reaches 293 K (20 °C) a linear heat build of 15 K (15 °C) begins. The fuel shall be heated in such a way that the temperature of the fuel during the heating conforms to the function below to within ±1.5 K. The elapsed time of the heat build and temperature rise is recorded.

$$T_r = T_o + 0.2333 \cdot t$$

Where:

T_r = required temperature (K),

T_o = initial temperature (K),

t = time from start of the tank heat build in minutes.

5.1.5.7 As soon as break-through occurs or when the fuel temperature reaches 308 K (35 °C), whichever occurs first, the heat source is turned off, the enclosure doors unsealed and opened, and the vehicle fuel tank cap(s) removed. If break-through has not occurred by the time the fuel temperature 308 K (35 °C), the heat source is removed from the vehicle, the vehicle removed from the evaporative emission enclosure and the entire procedure outlined in clause 5.1.7 of this Chapter repeated until break-through occurs.

5.1.6 **Butane loading to breakthrough**

5.1.6.1 If the enclosure is used for the determination of the break-through (see clause 5.1.4.2 of this Chapter) the vehicle shall be placed, with the engine shut off, in the evaporative emission enclosure

5.1.6.2 The evaporative emission canister shall be prepared for the canister loading operation. The canister shall not be removed from the vehicle, unless access to it in its normal location is so restricted that loading can only reasonably be accomplished by removing the canister from the vehicle. Special care shall be taken during this step to avoid damage to the components and the integrity of the fuel system.

5.1.6.3 The canister is loaded with a mixture composed of 50% butane and 50% nitrogen by volume at a rate of 40 grams butane per hour.

5.1.6.4 As soon as the canister reaches breakthrough, the vapour source shall be shut off.

5.1.6.5 The evaporative emission canister shall then be reconnected and the vehicle restored to its normal operating condition.

5.1.7 **Fuel drain and refill**

5.1.7.1 The fuel tank(s) of the vehicle(s) is (are) emptied using the fuel tank drain(s). This shall be done so as not to abnormally purge or abnormally load the evaporative control devices fitted to the vehicle. Removal of the fuel cap is normally sufficient to achieve this.

5.1.7.2 The fuel tank(s) is (are) refilled with test fuel at a temperature of between 291 ±8 K (18 ±8 °C) to 40 +2% of the tank's normal volumetric capacity. The fuel cap(s) of the vehicle shall be fitted at this point.

5.2 Preconditioning Drive

5.2.1 Within 1hour from the completing of canister loading in accordance with clauses 5.1.5 or 5.1.6 of this Chapter, the vehicle is placed on the chassis dynamometer and driven through one Part One and two Part Two driving cycles of Type I Test as specified in Chapter 3. Exhaust emissions are not sampled during this operation.

5.3 Soak

5.3.1 Within 5 minutes of completing the preconditioning operation specified in paragraph 5.2.1 of this Chapter the engine bonnet shall be completely closed and the vehicle driven off the chassis dynamometer and parked in the soak area. The vehicle is parked for a minimum of 12 hours and a maximum of 36 hours. The engine oil and coolant temperatures shall have reached the temperature of the area or within ±3 K of it at the end of the period.

5.4 Dynamometer Test

5.4.1 After conclusion of the soak period the vehicle is driven through a complete Type I Test drive as described in Chapter 3 of this Part (cold start urban and extra urban test). Then the engine is shut off. Exhaust emissions may be sampled during this operation but the results shall not be used for the purpose of exhaust emission type approval.

5.4.2 Within 2 minutes of completing the Type I Test drive specified in clause 5.4.1 of this Chapter the vehicle is driven a further conditioning drive consisting of one urban test cycle (hot start) of a Type I Test. Then the engine is shut off again. Exhaust emissions need not be sampled during this operation.

5.5 Hot Soak Evaporative Emissions Test

5.5.1 Before the completion of the test run the measuring chamber shall be purged for several minutes until a stable hydrocarbon background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.

5.5.2 The hydrocarbon analyzer shall be zeroed and spanned immediately prior to the test.

5.5.3 At the end of the driving cycle the engine bonnet shall be completely closed and all connections between the vehicle and the test stand disconnected. The vehicle is then driven to the measuring chamber with a minimum use of the accelerator pedal. The engine shall be turned off before any part of the vehicle enters the measuring chamber. The time at which the engine is switched off is recorded on the evaporative emission measurement data recording system and temperature recording begins. The vehicle's windows and luggage compartments shall be opened at this stage, if not already opened.

5.5.4 The vehicle shall be pushed or otherwise moved into the measuring chamber with the engine switched off.

5.5.5 The enclosure doors are closed and sealed gas-tight within 2 minutes of the engine being switched off and within 7 minutes of the end of the conditioning drive.

5.5.6 The start of a 60 ±0.5 minute hot soak period begins when the chamber is sealed. The hydrocarbon concentration, temperature and barometric pressure are measured to give the initial readings C_{HCi}, P_i and T_i for the hot soak test. These figures are used in the evaporative emission calculation, clause 6 of this Chapter. The ambient temperature T of the enclosure shall not be less than 296 K and no more than 304 K during the 60 minute hot soak period.

5.5.7 The hydrocarbon analyzer shall be zeroed and spanned immediately before the end of the 60 ±0.5 minute test period.

5.5.8 At the end of the 60 ±0.5 minute test period, the hydrocarbon concentration in the chamber shall be measured. The temperature and the barometric pressure are also measured. These are the final readings C_{HCf}, P_f and T_f for the hot soak test used for the calculation in clause 6 of this Chapter.

5.6 Soak

5.6.1 The test vehicle shall be pushed or otherwise moved to the soak area without use of the engine and soaked for not less than 6 hours and not more than 36 hours between the end of the hot soak test and the start of the diurnal emission test. For at least 6 hours of this period the vehicle shall be soaked at 293 ±2 K (20 ±2 °C).

5.7 Diurnal Test

5.7.1 The test vehicle shall be exposed to one cycle of ambient temperature according to the profile specified in Table 1 in Chapter 6 of this Part with a maximum deviation of ±2 K at any time. The average temperature deviation from the profile, calculated using the absolute value of each measured deviation, shall not exceed ±1 K. Ambient temperature shall be measured at least every minute. Temperature cycling begins when time T_{start} = 0, as specified in clause 5.7.6 of this Chapter.

5.7.2 The measuring chamber shall be purged for several minutes immediately before the test until a stable background is obtainable. The chamber mixing fan(s) shall also be switched on at this time.

5.7.3 The test vehicle, with the engine shut off and the test vehicle windows and luggage compartment(s) opened shall be moved into the measuring chamber. The mixing fan(s) shall be adjusted in such a way as to maintain a minimum air circulation speed of 8 km/h under the fuel tank of the test vehicle.

5.7.4 The hydrocarbon analyzer shall be zeroed and spanned immediately before the test.

5.7.5 The enclosure doors shall be closed and gas-tight sealed.

5.7.6 Within 10 minutes of closing and sealing the doors, the hydrocarbon concentration, temperature and barometric pressure are measured to give the initial readings C_{HCi}, P_i and T_i for the diurnal test. This is the point where time T_{start} = 0.

5.7.7 The hydrocarbon analyser shall be zeroed and spanned immediately before the end of the test.

5.7.8 The end of the emission sampling period occurs 24 hours ±6 minutes after the beginning of the initial sampling, as specified in clause 5.7.6. of this Chapter. The time elapsed is recorded. The hydrocarbon concentration, temperature and barometric pressure are measured to give the final readings C_{HCf}, P_f and T_f for the diurnal test used for the calculation in clause 6 of this Chapter. This completes the evaporative emission test procedure.

6.0 CALCULATION

6.1 The evaporative emission tests described in clause 5 of this Chapter allow the hydrocarbon emissions from the diurnal and hot soak phases to be calculated. Evaporative losses from each of these phases is calculated using the initial and final hydrocarbon concentrations, temperatures and pressures in the enclosure, together with the net enclosure volume. The formula below is used:

$$M_{HC} = K * V * 10^{-4}\left(\frac{C_{HC,f} * P_f}{T_f} - \frac{C_{HC,i} * P_i}{T_i}\right) + M_{HC,out} - M_{HC,i}$$

Where:

M_{HC} = Hydrocarbon mass in grams,

$M_{HC,out}$ = Mass of hydrocarbon exiting the enclosure, in the case of fixed volume enclosures for diurnal emission testing (grams),

$M_{HC,i}$ = mass of hydrocarbon entering the enclosure, in the case of fixed- volume enclosures for diurnal emission testing (grams),

C_{HC} = Measured hydrocarbon concentration in the enclosure (ppm volume in C_1 equivalent),

V = net enclosure volume in cubic metres corrected for the volume of the vehicle, with the windows and the luggage compartment open. If the volume of the vehicle is not determined a volume of 1.42 m^3 is subtracted,

T = ambient chamber temperature, in K,

P = barometric pressure in kPa,

H/C = hydrogen to carbon ratio,

k = $1.2 \cdot (12 + H/C)$;

Where:

i = is the initial reading

f = is the final reading

H/C = is taken to be 2.33 for diurnal test losses

H/C = is taken to be 2.20 for hot soak losses

6.2 **Overall Results of Test**

The overall hydrocarbon mass emission for the vehicle is taken to be:

$M_{total} = M_{DI} + M_{HS}$

Where:

M_{total} = overall mass emissions of the vehicle (grams),

M_{DI} = hydrocarbon mass emission for diurnal test (grams),

M_{HS} = hydrocarbon mass emission for the hot soak (grams).

7.0 CONFORMITY OF PRODUCTION

7.1 For routine end-of-production-line testing, the holder of the approval may demonstrate compliance by sampling vehicles which shall meet the following requirements.

7.2 **Test for Leakage**

7.2.1 Vents to the atmosphere from the emission control system shall be isolated.

7.2.2 A pressure of 370mm ±10 mm of H_2O shall be applied to the fuel system.

7.2.3 The pressure shall be allowed to stabilize prior to isolating the fuel system from the pressure source.

7.2.4 Following isolation of the fuel system, the pressure shall not drop by more than 50 mm of H_2O in 5 minutes.

7.3 **Test for Venting**

7.3.1 Vents to the atmosphere from the emission control shall be isolated.

7.3.2 A pressure of 370mm ±10 mm of H_2O shall be applied to the fuel system.

7.3.3 The pressure shall be allowed to stabilize prior to isolating the fuel system from the pressure source.

7.3.4 The venting outlets from the emission control systems to the atmosphere shall be reinstated to the production condition.

7.3.5 The pressure of the fuel system shall drop to below 100 mm of H_2O in not less than 30 seconds but within 2 minutes.

7.3.6 At the request of the manufacturer the functional capacity for venting can be demonstrated by equivalent alternative procedure. The specific procedure should be demonstrated by the manufacturer to the Test Agency during the type approval procedure.

7.4 **Purge Test**

7.4.1 Equipment capable of detecting an airflow rate of 1.0 litres in one minute shall be attached to the purge inlet and a pressure vessel of sufficient size to have negligible effect on the purge system shall be connected via a switching valve to the purge inlet, or alternatively.

7.4.2 The manufacturer may use a flow meter of his own choosing, if acceptable to the Test Agency.

7.4.3 The vehicle shall be operated in such a manner that any design feature of the purge system that could restrict purge operation is detected and the circumstances noted.

7.4.4 Whilst the engine is operating within the bounds noted in clause 7.4.3 of this Chapter, the air flow shall be determined by either:

7.4.4.1 The device indicated in clause 7.4.1 of this Chapter being switched in. A pressure drop from atmospheric to a level indicating that a volume of 1.0 litres of air has flowed into the evaporative emission control system within one minute shall be observed; or

7.4.4.2 If an alternative flow measuring device is used, a reading of no less than 1.0 litre per minute shall be detectable.

7.4.4.3 At the request of the manufacturer an alternative purge tat procedure can be used, if the procedure has been presented to and has been accepted by the Test Agency during the type approval procedure.

7.5 The Test Agency which has granted type approval may at any time verify the conformity control methods applicable to each production unit.

7.5.1 The Test Agency shall take a sufficiently large sample from the series.

7.5.2 The Test Agency may test these vehicles by application of clause 7.1 of this Chapter.

7.6 If the requirements of clause 7.5 of this Chapter are not met, the Test Agency shall ensure that all necessary steps are taken to re-establish conformity of production as rapidly as possible.

8.0. **Manufacturer can opt for SHED (DBL + HST) test as defined in this chapter for Conformity of Production instead of procedure described in clause 7.0 of this Chapter.**

CHAPTER 12

TYPE V TEST

DESCRIPTION OF THE ENDURANCE TEST FOR VERIFYING THE DURABILITY OF POLLUTION CONTROL DEVICES

1.0 INTRODUCTION

1.1 This Chapter describes the test for verifying the durability of anti-pollution devices equipping vehicles with positive-ignition or compression-ignition engines. The durability requirements shall be demonstrated using one of the three options set out in clauses 1.2, 1.3 and 1.4. of this Chapter.

1.2 The whole vehicle durability test represents an ageing test of 160,000 km. This test is to be performed driven on a test track, on the road, or on a chassis dynamometer.

1.3 The manufacturer may choose to use a bench ageing durability test as defined in clause 2.2 of this Chapter.

1.4 As an alternative to durability testing, a manufacturer may choose to apply the assigned deterioration factors as per said Gazette Notification.

1.5 At the request of the manufacturer, the Test Agency may carry out the Type I Test before the whole vehicle or bench ageing durability test has been completed using the assigned deterioration factors defined in said Gazette Notification. On completion of the whole vehicle or bench ageing durability test, the Test Agency may then amend the type approval results by replacing the assigned deterioration factors in the said Gazette Notification with those measured in the whole vehicle or bench ageing durability test.

1.6 Deterioration factors are determined using either the procedures set out in clauses 1.2 and 1.3 of this Chapter or using the assigned values in the Gazette Notification. The deterioration factors are used to establish compliance with the requirements of the appropriate emissions limits set out in said notification during the useful life of the vehicle.

2.0 TECHNICAL REQUIREMENTS

2.1 As an alternative to the operating cycle described in clause 6.1 of this Chapter for the whole vehicle durability test the vehicle manufacturer may use Standard Road Cycle (SRC) described in this Chapter. This test cycle shall be conducted until the vehicle has covered a minimum of 160,000 km.

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2.2 **Bench Ageing Durability Test**

2.2.1 In addition to the technical requirements for the bench ageing test set out in clause 1.3 of this Chapter, the technical requirements set out in clause 2 of this Chapter shall apply.

2.3 The fuel to be used during the test shall be the one specified in clause 4 of this Chapter.

2.3.1 **Vehicles with Positive Ignition Engines**

2.3.1.1 The following bench ageing procedure shall be applicable for positive ignition vehicles including hybrid vehicles which use a catalyst as the principle after- treatment emission control device.

The bench ageing procedure requires the installation of the catalyst-plus oxygen sensor system on a catalyst ageing bench.

Ageing on the bench shall be conducted by following the Standard Bench Cycle (SBC) for the period of time calculated from the Bench Ageing Time (BAT) equation. The BAT equation requires, as input, catalyst time-at temperature data measured on the Standard Road Cycle (SRC), described in this chapter.

2.3.1.2 Standard Bench Cycle (SBC). Standard catalyst bench ageing shall be conducted following the SBC. The SBC shall be run for the period of time calculated from the BAT equation. The SBC is described in Appendix 1 of this Chapter.

2.3.2.3 Catalyst time-at-temperature data: Catalyst temperature shall be measured during at least two full cycles of the SRC cycle as described in Appendix 3 of this Chapter.

Catalyst temperature shall be measured at the highest temperature location in the hottest catalyst on the test vehicle. Alternatively, the temperature may be measured at another location providing that it is adjusted to represent the temperature measured at the hottest location using good engineering judgement.

Catalyst temperature shall be measured at a minimum rate of one hertz (one measurement per second).

The measured catalyst temperature results shall be tabulated into a histogram with temperature groups of no larger than 25 °C.

2.3.1.4 Bench-Ageing Time: Bench ageing time shall be calculated using the bench ageing time (BAT) equation as follows:

te for a temperature bin = th $e^{((R/T_r)-(R/T_v))}$

Total te = Sum of te over all the temperature groups

Bench-Ageing Time = A (Total te)

Where:

A = This value adjusts the catalyst ageing time to account for deterioration from sources other than thermal ageing of the catalyst.

R = Catalyst thermal reactivity = 17,500

th = The time (in hours) measured within the prescribed temperature bin of the vehicle's catalyst temperature histogram adjusted to a full useful life basis e.g., if the histogram represented 400 km, and useful life is 160,000 km; all histogram time entries would be multiplied by 400 (160,000/400).

Total te = The equivalent time (in hours) to age the catalyst at the temperature of T_r on the catalyst ageing bench using the catalyst ageing cycle to produce the same amount of deterioration experienced by the catalyst due to thermal deactivation over the 160,000 km.

te for a bin = The equivalent time (in hours) to age the catalyst at the temperature of T_r on the catalyst ageing bench using the catalyst ageing cycle to produce the same amount of deterioration experienced by the catalyst due to thermal deactivation at the temperature bin of T_v over 160,000 km.

T_r = The effective reference temperature (in K) of the catalyst on the catalyst bench run on the bench ageing cycle. The effective temperature is the constant temperature that would result in the same amount of ageing as the various temperatures experienced during the bench ageing cycle.

T_v = The mid-point temperature (in K) of the temperature bin of the vehicle on-road catalyst temperature histogram.

2.3.1.5 Effective reference temperature on the SBC. The effective reference temperature of the standard bench cycle (SBC) shall be determined for the actual catalyst system design and actual ageing bench which will be used using the following procedures:

(a) Measure time-at-temperature data in the catalyst system on the catalyst ageing bench following the SBC. Catalyst temperature shall be measured at the highest temperature location of the hottest catalyst in the system. Alternatively, the temperature may be measured at another location providing that it is adjusted to represent the temperature measured at the hottest location.

Catalyst temperature shall be measured at a minimum rate of one hertz (one measurement per second) during at least 20 minutes of bench ageing. The measured catalyst temperature results shall be tabulated into a histogram with temperature groups of no larger than 10 °C.

(b) The BAT equation shall be used to calculate the effective reference temperature by iterative changes to the reference temperature (T_r) until the calculated ageing time equals or exceeds the actual time represented in the catalyst temperature histogram. The resulting temperature is the effective reference temperature on the SBC for that catalyst system and ageing bench.

2.3.1.6 Catalyst Ageing Bench. The catalyst ageing bench shall follow the SBC and deliver the appropriate exhaust flow, exhaust constituents, and exhaust temperature at the face of the catalyst.

All bench ageing equipment and procedures shall record appropriate information (such as measured A/F ratios and time-at-temperature in the catalyst) to assure that sufficient ageing has actually occurred.

2.3.1.7 Required Testing. For calculating deterioration factors at least two Type I Tests before bench ageing of the emission control hardware and at least two Type I Tests after the bench-aged emission hardware is reinstalled have to be performed on the test vehicle.

Additional testing may be conducted by the manufacturer. Calculation of the deterioration factors has to be done according to the calculation method as specified in clause 7. of this chapter.

2.3.2 **Vehicles with Compression Ignition Engines**

2.3.2.1 The following bench ageing procedure is applicable for compression-ignition vehicles including hybrid vehicles.

The bench ageing procedure requires the installation of the after-treatment system on a after-treatment system ageing bench.

Ageing on the bench is conducted by following the Standard Diesel Bench Cycle (SDBC) for the number of regenerations / desulphurisations calculated from the Bench Ageing Duration (BAD) equation.

2.3.2.2 Standard Diesel Bench Cycle (SDBC). Standard bench ageing is conducted following the SDBC. The SDBC shall be run for the period of time calculated from the Bench Ageing Duration (BAD) equation. The SDBC is described in Appendix 2 of this Chapter.

2.3.2.3 Regeneration data. Regeneration intervals shall be measured during at least 10 full cycles of the SRC cycle described in Appendix 3 of this Chapter. As an alternative the intervals from the K_i determination may be used.

If applicable, desulphurisation intervals shall also be considered based on manufacturer's data.

2.3.2.4 Diesel bench-ageing duration. Bench ageing duration is calculated using the BAD equation as follows:

Bench-Ageing Duration = number of regeneration and/or desulphurisation cycles (whichever is the longer) equivalent to 160,000 km of driving.

2.3.2.5 Ageing Bench. The ageing bench shall follow the SDBC and deliver appropriate exhaust flow, exhaust constituents, and exhaust temperature to the after-treatment system inlet.

The manufacturer shall record the number of regenerations / desulphurisations (if applicable) to assure that sufficient ageing has actually occurred.

2.3.2.6 Required Testing. For calculating deterioration factors at least two Type I Tests before bench ageing of the emission control hardware and at least two Type I Tests after the bench-aged emission hardware is reinstalled have to be performed. Additional testing may be conducted by the manufacturer. Calculation of the deterioration factors shall be done according to the calculation method set out in clause 7. of this Chapter and with the additional requirements contained in this Part.

3.0 TEST VEHICLE

3.1 The vehicle shall be in good mechanical order; the engine and the antipollution devices shall be new. The vehicle may be the same as that presented for the Type I Test; this Type I Test has to be done after the vehicle has run at least 3,000 km of the ageing cycle of clause 6.1 of this Chapter.

4.0 FUEL

The durability test is conducted with a suitable commercially available fuel

5.0 VEHICLE MAINTENANCE AND ADJUSTMENTS

Maintenance, adjustments as well as the use of the test vehicle's controls shall be those recommended by the manufacturer.

6.0 VEHICLE OPERATION ON TRACK, ROAD OR ON CHASSIS DYNAMOMETER

6.1 OPERATING CYCLE

During operation on track, road or on roller test bench, the distance shall be covered according to the driving schedule (Figure 1 of this Chapter) described below:

6.1.1 The durability test schedule is composed of 11 cycles covering 6 kilometres each,

6.1.2 During the first nine cycles, the vehicle is stopped four times in the middle of the cycle, with the engine idling each time for 15 seconds,

6.1.3 Normal Acceleration and Deceleration,

6.1.4 Five decelerations in the middle of each cycle, dropping from cycle speed to 32 km/h, and the vehicle is gradually accelerated again until cycle speed is attained,

6.1.5 The 10^{th} cycle is carried out at a steady speed of 72 km/h,

6.1.6 The 11^{th} cycle begins with maximum acceleration from stop point up to 90 km/h. At half-way, braking is employed normally until the vehicle comes to a stop. This is followed by an idle period of 15 seconds and a second maximum acceleration.

The schedule is then restarted from the beginning.

The maximum speed of each cycle is given in the following Table 1 of this Chapter.

Table 1
Maximum Speed of Each Cycle

Cycle	Cycle speed in km/h
1	64
2	48
3	64
4	64
5	56
6	48
7	56
8	72
9	56
10	72
11	90

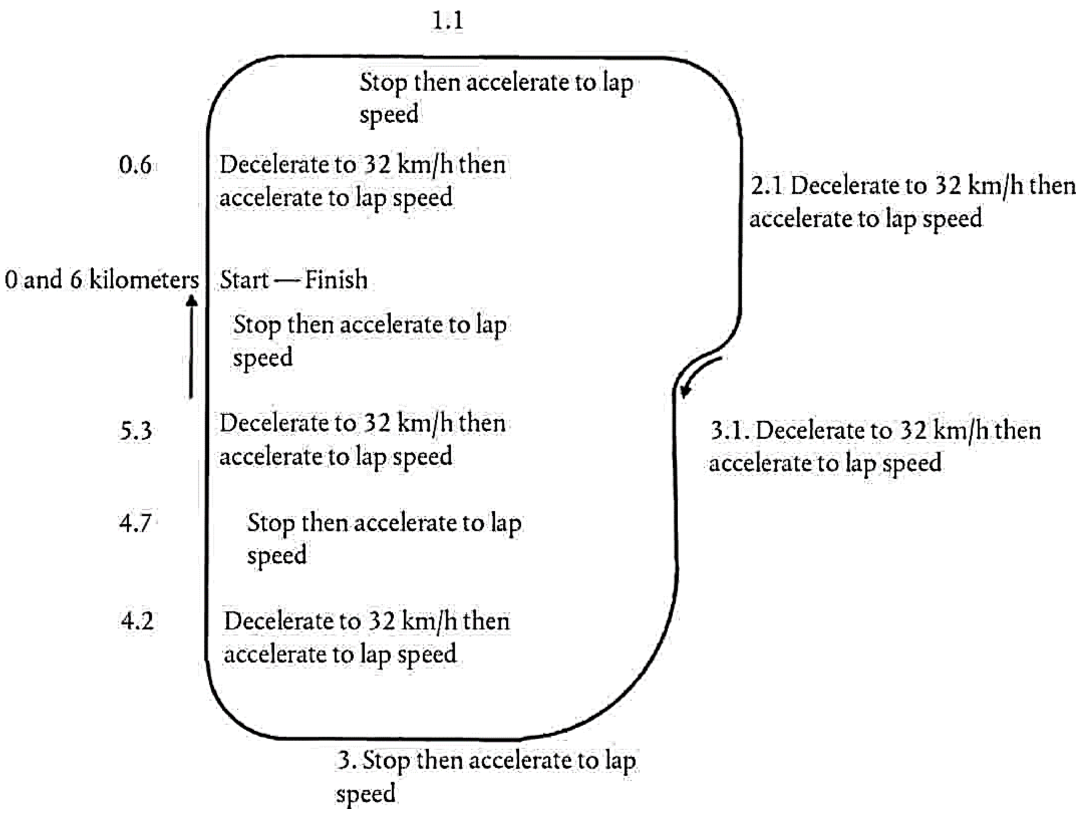


Figure 1
Driving Schedule

6.2 The durability test, or if the manufacturer has chosen, the modified durability test shall be conducted until the vehicle has covered a minimum of 160,000 km.

6.3 **Test Equipment**

6.3.1 **Chassis Dynamometer**

6.3.1.1 When the durability test is performed on a chassis dynamometer, the dynamometer shall enable the cycle described in clause 6.1 of this Chapter. to be carried out. In particular, it shall be equipped with systems simulating inertia and resistance to progress.

6.3.1.2 The brake shall be adjusted in order to absorb the power exerted on the driving wheels at a steady speed of 80 km/h. Methods to be applied to determine this power and to adjust the brake are the same as those described in Appendix 2 of Chapter 5 of this Part.

6.3.1.3 The vehicle cooling system should enable the vehicle to operate at temperatures similar to those obtained on road (oil, water, exhaust system, etc.).

6.3.1.4 Certain other test bench adjustments and feature are deemed to be identical, where necessary to those described in Chapter 3 (inertia for example which may be electronic or mechanical).

6.3.1.5. The vehicle may be moved, where necessary, to a different bench in order to conduct emission measurement tests.

6.3.2 **Operation on Track or Road**

When the durability test is completed on track or road, the vehicle's reference mass will be at least equal to that retained for tests conducted on a chassis dynamometer.

7.0 MEASURING EMISSIONS OF POLLUTANTS

At the start of the test (0 km), and every 10,000 km (±400 km) or more frequently, at regular intervals until having covered 160,000 km, exhaust emissions are measured in accordance with the Type I Test as defined in clause 5.3.1 of Chapter 1 of this Part. The limit values to be complied with are those laid down in clause 5.3.1.4 of Chapter 1 of this Part.

In the case of vehicles equipped with periodically regenerating systems as defined in clause 2.20 of Chapter 1 of this Part, it shall be checked that the vehicle is not approaching a regeneration period. If this is the case, the vehicle must be driven until the end of the regeneration. If a regeneration occurs during the emissions measurement, a new test (including preconditioning) shall be performed, and the first result not taken into account.

All exhaust emissions results shall be plotted as a function of the running distance on the system rounded to the nearest kilometer and the best fit straight line fitted by the method of least squares shall be drawn through all these data points. This calculation shall not take into account the test results at 0 km.

The data will be acceptable for use in the calculation of the deterioration factor only if the interpolated 6,400 km and 160,000 km points on this line are within the above mentioned limits.

The data are still acceptable when a best fit straight line crosses an applicable limit with a negative slope (the 6,400 km interpolated point is higher than the 160,000 km interpolated point) but the 160,000 km actual data point is below the limit.

A multiplicative exhaust emission deterioration factor shall be calculated for each pollutant as follows:

$$D.E.F. = \frac{Mi_2}{Mi_1}$$

Where:

Mi_1 = mass emission of the pollutant i in g/km interpolated to 6,400 km,

Mi_2 = mass emission of the pollutant i in g/km interpolated to 160,000 km.

These interpolated values shall be carried out to a minimum of four places to the right of the decimal point before dividing one by the other to determine the deterioration factor. The result shall be rounded to three places to the right of the decimal point.

If a deterioration factor is less than one, it is deemed to be equal to one.

At the request of a manufacturer, an additive exhaust emission deterioration factor shall be calculated for each pollutant as follows:

$$D.E.F. = Mi_2 - Mi_1$$

CHAPTER 12 - APPENDIX 1

STANDARD BENCH CYCLE (SBC)

1.0 INTRODUCTION

The standard ageing durability procedure consists of ageing a catalyst/oxygen sensor system on an ageing bench which follows the Standard Bench Cycle (SBC) described in this Appendix The SBC requires the use of an ageing bench with an engine as the source of feed gas for the catalyst. The SBC is a 60-second cycle which is repeated as necessary on the ageing bench to conduct ageing for the required period of time. The SBC is defined based on the catalyst temperature, engine air/fuel (A/F) ratio, and the amount of secondary air injection which is added in front of the first catalyst.

2.0 CATALYST TEMPERATURE CONTROL

2.1 Catalyst temperature shall be measured in the catalyst bed at the location where the highest temperature occurs in the hottest catalyst. Alternatively, the feed gas temperature may be measured and converted to catalyst bed temperature using a linear transform calculated from correlation data collected on the catalyst design and ageing bench to be used in the ageing process.

2.2 Control the catalyst temperature at stoichiometric operation (01 to 40 seconds on the cycle) to a minimum of 800 °C (±10° C) by selecting the appropriate engine speed, load, and spark timing for the engine. Control the maximum catalyst temperature that occurs during the cycle to 890 °C (±10 °C) by selecting the appropriate A/F ratio of the engine during the "rich" phase described in the Table 1 of this Appendix.

2.3 If a low control temperature other than 800 °C is utilized, the high control temperature shall be 90 °C higher than the low control temperature.

Table 1
Standard Bench Cycle (SBC)

Time (seconds)	Engine Air/Fuel Ratio	Secondary Air Injection
1-40	Stoichiometric with load, spark timing and engine speed controlled to achieve a minimum catalyst temperature of 800 °C.	None
41-45	"Rich" (A/F ratio selected to achieve a maximum catalyst temperature over the entire cycle of 890°C or 90°C higher than lower control temperature)	None

46-55	"Rich" (A/F ratio selected to achieve a maximum catalyst temperature over the entire cycle of 890 °C or 90 °C higher than lower control temperature)	3 % (±1%)
56-60	Stoichiometric with load, spark timing and engine speed controlled to achieve a minimum catalyst temperature of 800 °C	3 % (±1%)

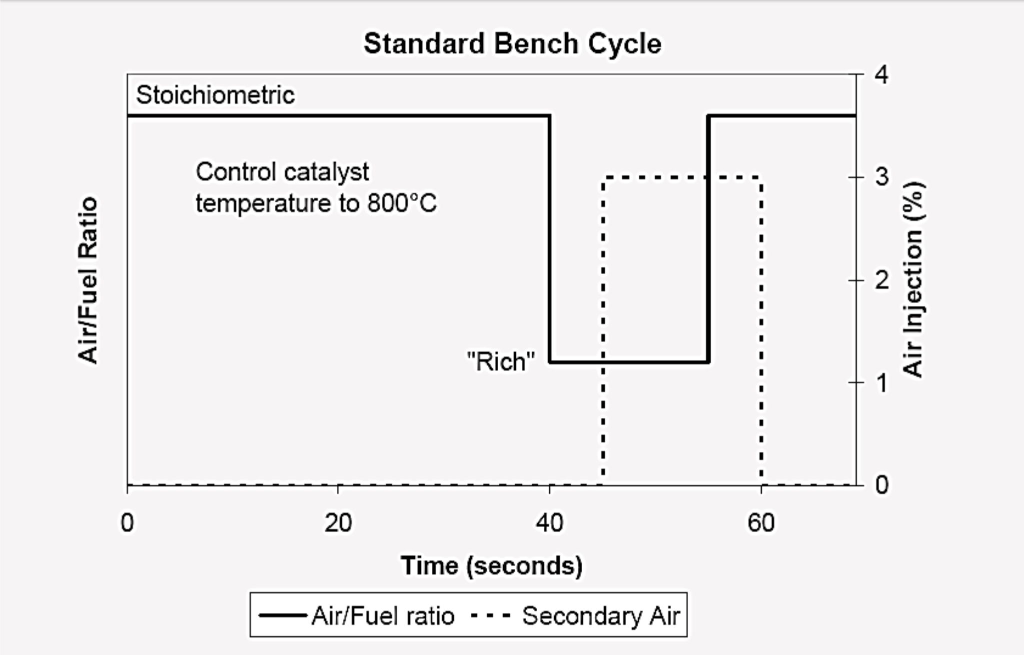


Figure 1
Standard Bench Cycle

3.0 AGEING BENCH EQUIPMENT AND PROCEDURES

3.1 Ageing Bench Configuration. The ageing bench shall provide the appropriate exhaust flow rate, temperature, air-fuel ratio, exhaust constituents and secondary air injection at the inlet face of the catalyst.

The standard ageing bench consists of an engine, engine controller, and engine dynamometer. Other configurations may be acceptable (e.g. whole vehicle on a dynamometer, or a burner that provides the correct exhaust conditions), as long as the catalyst inlet conditions and control features specified in this Chapter are met.

A single ageing bench may have the exhaust flow split into several streams providing that each exhaust stream meets the requirements of this Appendix. If the bench has more than one exhaust stream, multiple catalyst systems may be aged simultaneously.

3.2 Exhaust System Installation. The entire catalyst(s)-plus-oxygen sensor(s) system, together with all exhaust piping which connects these components, will be installed on the bench. For engines with multiple exhaust streams (such as some V6 and V8 engines), each bank of the exhaust system will be installed separately on the bench in parallel.

For exhaust systems that contain multiple in-line catalysts, the entire catalyst system including all catalysts, all oxygen sensors and the associated exhaust piping will be installed as a unit for ageing. Alternatively, each individual catalyst may be separately aged for the appropriate period of time.

3.3 Temperature Measurement. Catalyst temperature shall be measured using a thermocouple placed in the catalyst bed at the location where the highest temperature occurs in the hottest catalyst. Alternatively, the feed gas temperature just before the catalyst inlet face may be measured and converted to catalyst bed temperature using a linear transform calculated from correlation data collected on the catalyst design and ageing bench to be used in the ageing process. The catalyst temperature shall be stored digitally at the speed of 1 Hz (one measurement per second).

3.4 Air/Fuel Measurement. Provisions shall be made for the measurement of the air/fuel (A/F) ratio (such as a wide-range oxygen sensor) as close as possible to the catalyst inlet and outlet flanges. The information from these sensors shall be stored digitally at the speed of 1 Hz (one measurement per second).

3.5 Exhaust Flow Balance. Provisions shall be made to assure that the proper amount of exhaust (measured in grams/second at stoichiometry, with a tolerance of ±5 grams/ second) flows through each catalyst system that is being aged on the bench.

The proper flow rate is determined based upon the exhaust flow that would occur in the original vehicle’s engine at the steady state engine speed and load selected for the bench ageing.

3.6 Setup. The engine speed, load, and spark timing are selected to achieve a catalyst bed temperature of 800 °C (±10 °C) at steady-state stoichiometric operation.

The air injection system is set to provide the necessary air flow to produce 3.0% oxygen (±0.1%) in the steady-state stoichiometric exhaust stream just in front of the first catalyst. A typical reading at the upstream A/F measurement point (required in clause 3.4 of this Appendix) is lambda 1.16 (which is approximately 3% oxygen).

With the air injection on, set the "Rich" A/F ratio to produce a catalyst bed temperature of 890 °C (±10 °C). A typical A/F value for this step is lambda 0.94 (approximately 2% CO).

3.7 Ageing Cycle. The standard bench ageing procedures use the standard bench cycle (SBC). The SBC is repeated until the amount of ageing calculated from the bench ageing time equation (BAT) is achieved.

3.8 Quality Assurance. The temperatures and A/F ratio in clauses 3.3 and 3.4 of this Appendix shall be reviewed periodically (at least every 50 hours) during ageing. Necessary adjustments shall be made to assure that the SBC is being appropriately followed throughout the ageing process.

After the ageing has been completed, the catalyst time-at-temperature collected during the ageing process shall be tabulated into a histogram with temperature groups of no larger than 10 °C. The BAT equation and the calculated effective reference temperature for the ageing cycle according to clause 2.3.1.4 of this Chapter will be used to determine if the appropriate amount of thermal ageing of the catalyst has in fact occurred. Bench ageing will be extended if the thermal effect of the calculated ageing time is not at least 95% of the target thermal ageing.

3.9 Startup and Shutdown. Care should be taken to assure that the maximum catalyst temperature for rapid deterioration (e.g.,1050 °C) does not occur during startup or shutdown. Special low temperature startup and shutdown procedures may be used to alleviate this concern.

4.0 EXPERIMENTALLY DETERMINING THE R-FACTOR FOR BENCH AGEING DURABILITY PROCEDURES

4.1 The R-Factor is the catalyst thermal reactivity coefficient used in the bench ageing time (BAT) equation. Manufacturers may determine the value of R experimentally using the following procedures.

4.1.1 Using the applicable bench cycle and ageing bench hardware, age several catalysts (minimum of 3 of the same catalyst design) at different control temperatures between the normal operating temperature and the damage limit temperature. Measure emissions (or catalyst inefficiency (1-catalyst efficiency)) for each exhaust constituent. Assure that the final testing yields data between one- and two-times the emission standard.

4.1.2 Estimate the value of R and calculate the effective reference temperature (Tr) for the bench ageing cycle for each control temperature according to clause 2.3.1.4. of this Chapter

4.1.3 Plot emissions (or catalyst inefficiency) versus ageing time for each catalyst. Calculate the least-squared best-fit line through the data. For the data set to be useful for this purpose the data should have an approximately common intercept between 0 and 6400 km. See the following graph in Figure 2 of this Appendix for an example.

4.1.4 Calculate the slope of the best-fit line for each ageing temperature.

4.1.5 Plot the natural log (ln) of the slope of each best-fit line (determined in clause 4.1.4.of this Appendix) along the vertical axis, versus the inverse of ageing temperature (1/(ageing temperature, deg K)) along the horizontal axis, Calculate the least squared best-fit lines through the data. The slope of the line is the R-factor.

See the following graph in Figure 2 of this Appendix for an example.

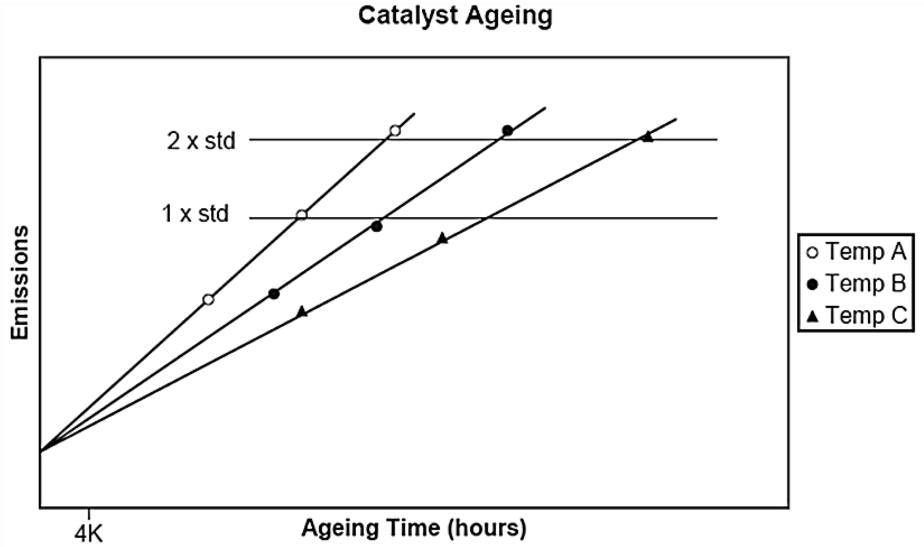
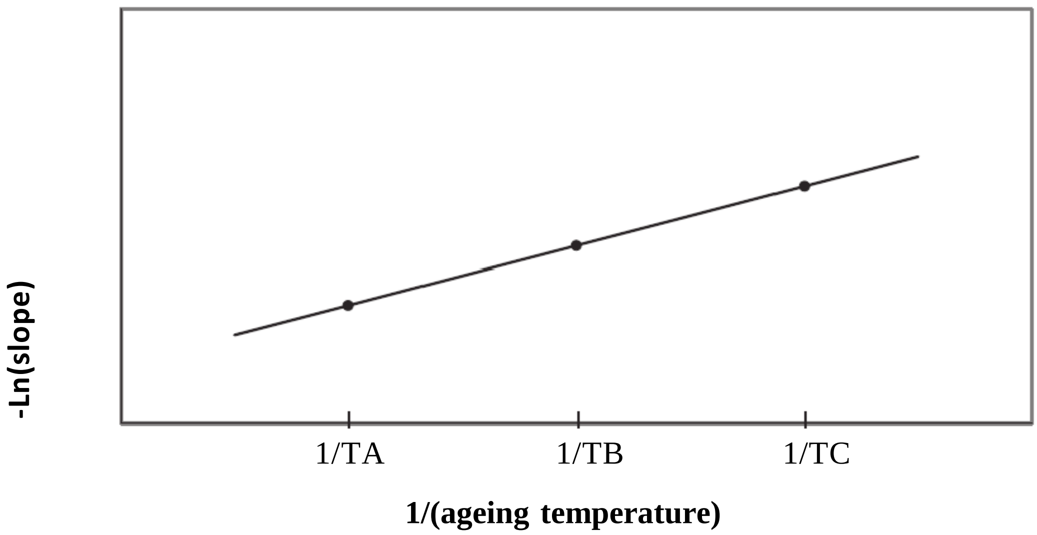


Figure 2

Example of Catalyst Ageing

4.1.6 Compare the R-factor to the initial value that was used in clause 4.1.2. of this Appendix. If the calculated R-factor differs from the initial value by more than 5%, choose a new R-factor that is between the initial and calculated values, and then repeat steps in clause 4.1.2 to 4.1.6 of this Appendix to derive a new R-factor. Repeat this process until the calculated R-factor is within 5% of the initially assumed R-factor.

4.1.7 Compare the R-factor determined separately for each exhaust constituent. Use the lowest R-factor (worst case) for the BAT equation.



Slope = rate of change in emissions/time

Figure 3
Determining the R-Factor

CHAPTER 12 – APPENDIX 2

STANDARD DIESEL BENCH CYCLE (SDBC)

1.0 INTRODUCTION

For particulate filters, the number of regenerations is critical to the ageing process. For systems that require desulphurisation cycles (e.g. NO_X storage catalysts), this process is also significant.

The standard diesel bench ageing durability procedure consists of ageing an after- treatment system on an ageing bench which follows the standard bench cycle (SDBC) described in this Appendix. The SDBC requires use of an ageing bench with an engine as the source of feed gas for the system.

During the SDBC, the regeneration / desulphurisation strategies of the system shall remain in normal operating condition.

2.0 The Standard Diesel Bench Cycle reproduces the engine speed and load conditions that are encountered in the SRC cycle as appropriate to the period for which durability is to be determined. In order to accelerate the process of ageing, the engine settings on the test bench may be modified to reduce the system loading times. For example the fuel injection timing or EGR strategy may be modified.

3.0 AGEING BENCH EQUIPMENT AND PROCEDURES

3.1 The standard ageing bench consists of an engine, engine controller, and engine dynamometer. Other configurations may be acceptable (e.g. whole vehicle on a dynamometer, or a burner that provides the correct exhaust conditions), as long as the after-treatment system inlet conditions and control features specified in this Appendix are met.

A single ageing bench may have the exhaust flow split into several streams provided that each exhaust stream meets the requirements of this Appendix. If the bench has more than one exhaust stream, multiple after-treatment systems may be aged simultaneously.

3.2 Exhaust System Installation : The entire after-treatment system, together with all exhaust piping which connects these components, will be installed on the bench. For engines with multiple exhaust streams (such as some V6 and V8 engines), each bank of the exhaust system will be installed separately on the bench.

The entire after-treatment system will be installed as a unit for ageing. Alternatively, each individual component may be separately aged for the appropriate period of time.

CHAPTER 12 - APPENDIX 3

STANDARD ROAD CYCLE (SRC)

1.0 INTRODUCTION

The Standard Road Cycle (SRC) is a kilometre accumulation cycle. The vehicle may be run on a test track or on a kilometre accumulation dynamometer.

The cycle consists of 7 laps of a 6 km course. The length of the lap may be changed to accommodate the length of the mileage accumulation test track.

Table 1

Standard Road cycle

Lap	Description	Typical acceleration rate m/s²
1	(start engine) idle 10 seconds	0
1	Moderate acceleration to 48 km/h	1.79
1	Cruise at 48 km/h for ¼ lap	0
1	Moderate deceleration to 32 km/h	-2.23
1	Moderate acceleration to 48 km/h	1.79
1	Cruise at 48 km/h for ¼ lap	0
1	Moderate deceleration to stop	-2.23
1	Idle 5 seconds	0
1	Moderate acceleration to 56 km/h	1.79
1	Cruise at 56 km/h for ¼ lap	0
1	Moderate deceleration to 40 km/h	-2.23
1	Moderate acceleration to 56 km/h	1.79
1	Cruise at 56 km/h for ¼ lap	0
1	Moderate deceleration to stop	-2.23
2	idle 10 seconds	0
2	Moderate acceleration to 64 km/h	1.34
2	Cruise at 64 km/h for ¼ lap	0
2	Moderate deceleration to 48 km/h	-2.23
2	Moderate acceleration to 64 km/h	1.34
2	Cruise at 64 km/h for ¼ lap	0
2	Moderate deceleration to stop	-2.23
2	Idle 5 seconds	0
2	Moderate acceleration to 72 km/h	1.34
2	Cruise at 72 km/h for ¼ lap	0
2	Moderate deceleration to 56 km/h	-2.23

2	Moderate acceleration to 72 km/h	1.34
2	Cruise at 72 km/h for ¼ lap	0
2	Moderate deceleration to stop	-2.23
3	idle 10 seconds	0
3	Hard acceleration to 88 km/h	1.79
3	Cruise at 88 km/h for ¼ lap	0
3	Moderate deceleration to 72 km/h	-2.23
3	Moderate acceleration to 88 km/h	0.89
3	Cruise at 88 km/h for ¼ lap	0
3	Moderate deceleration to 72 km/h	-2.23
3	Moderate acceleration to 97 km/h	0.89
3	Cruise at 97 km/h for ¼ lap	0
3	Moderate deceleration to 80 km/h	-2.23
3	Moderate acceleration to 97 km/h	0.89
3	Cruise at 97 km/h for ¼ lap	0
3	Moderate deceleration to stop	-1.79
4	idle 10 seconds	0
4	Hard acceleration to 129 km/h	
4	Coastdown to 113 km/h	-0.45
4	Cruise at 113 km/h for ½ lap	0
4	Moderate deceleration to 80 km/h	-1.34
4	Moderate acceleration to 105 km/h	0.89
4	Cruise at 105 km/h for ½ lap	0
4	Moderate deceleration to 80 km/h	-1.34
5	Moderate acceleration to 121 km/h	0.45
5	Cruise at 121 km/h for ½ lap	0
5	Moderate deceleration to 80 km/h	-1.34
5	Light acceleration to 113 km/h	0.45
5	Cruise at 113 km/h for ½ lap	0
5	Moderate deceleration to 80 km/h	-1.34
6	Moderate acceleration to 113 km/h	0.89
6	Coastdown to 97 km/h	-0.45
6	Cruise at 97 km/h for ½ lap	0
6	Moderate deceleration to 80 km/h	-1.79
6	Moderate acceleration to 104 km/h	0.45
6	Cruise at 104 km/h for ½ lap	0
6	Moderate deceleration to stop	-1.79
7	idle 45 seconds	0
7	Hard acceleration to 88 km/h	1.79
7	Cruise at 88 km/h for ¼ lap	0
7	Moderate deceleration to 64 km/h	-2.23

7	Moderate acceleration to 88 km/h	0.89
7	Cruise at 88 km/h for ¼ lap	0
7	Moderate deceleration to 64 km/h	-2.23
7	Moderate acceleration to 80 km/h	0.89
7	Cruise at 80 km/h for ¼ lap	0
7	Moderate deceleration to 64 km/h	-2.23
7	Moderate acceleration to 80 km/h	0.89
7	Cruise at 80 km/h for ¼ lap	0
7	Moderate deceleration to stop	-2.23

The standard road cycle is represented graphically in the following Figure 1:

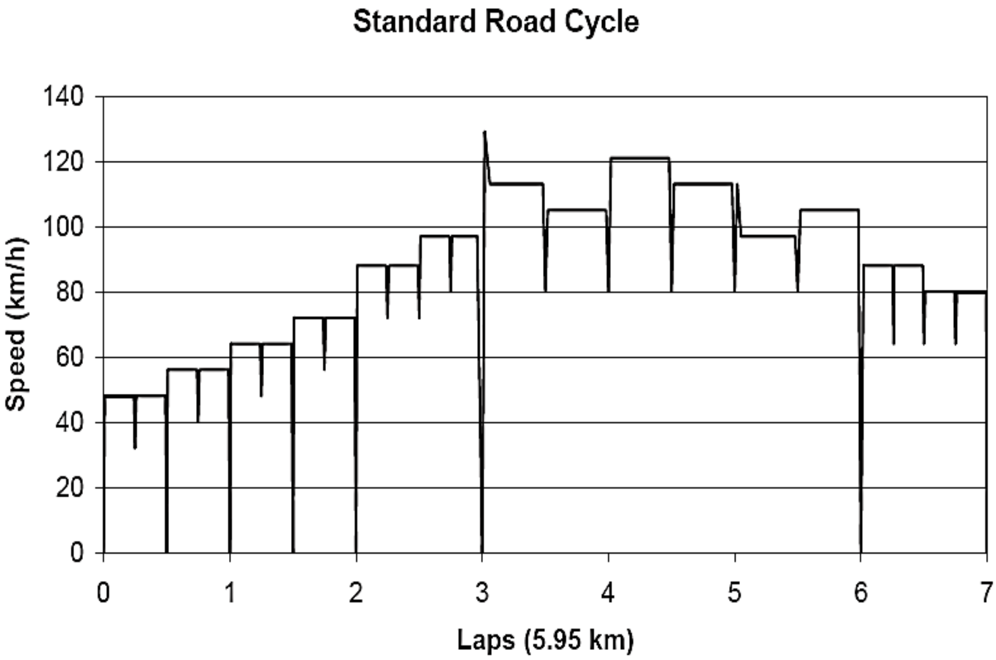


Figure 1
Standard Road Cycle

CHAPTER 13

GRANTING OF TYPE APPROVAL FOR A VEHICLE FUELLED BY LPG OR NG / BIOMETHANE

1.0 **INTRODUCTION**

This Chapter describes the special requirements that apply in the case of an approval of a vehicle that runs on LPG or NG/bio methane, or that can run either on gasoline or LPG or NG/bio methane in so far as the testing on LPG or NG/biomethane gas is concerned.

In the case of LPG and NG/biomethane natural gas there is on the market a large variation in fuel composition, requiring the fueling system to adapt its fueling rates to these compositions. To demonstrate this capability, the vehicle has to be tested in the test Type I on two extreme references fuels and demonstrate the self-adaptability of the fueling system. Whenever the self-adaptability of a fueling system has been demonstrated on a vehicle, such a vehicle may be considered as a parent of a family. Vehicles that comply with the requirements of members of that family, if fitted with the same fueling system, need to be tested on only one fuel.

2.0 **DEFINITIONS**

For the purpose of this Chapter the following definitions shall apply:

2.1 A **"family"** means a group of vehicle types fueled by LPG, NG/bio methane identified by a parent vehicle.

2.2. A **"parent vehicle"** means a vehicle that is selected to act as the vehicle on which the self-adaptability of a fueling system is going to be demonstrated, and to which the members of a family refer. It is possible to have more than one parent vehicle in a family.

2.3. **Member of the Family**

2.3.1. A **"member of the family"** is a vehicle that shares the following essential characteristics with its parent(s):

(a) It is produced by the same manufacturer;

(b) It is subject to the same emission limits;

(c) If the gas fueling system has a central metering for the whole engine:

It has a certified power output between 0.7 and 1.15 times that of the parent vehicle.

(d) If the gas fueling system has an individual metering per cylinder:

(e) It has a certified power output per cylinder between 0.7 and 1.15 times that of the parent vehicle.

(f) If fitted with a catalyst, it has the same type of catalyst i.e. three way, oxidation, de-NO_x.

(g) It has a gas fueling system (including the pressure regulator) from the same system manufacturer and of the same type: induction, vapour injection (single point, multipoint), liquid injection (single point, multipoint).

(h) This gas fueling system is controlled by an ECU of the same type and technical specification, containing the same software principles and control strategy. The vehicle may have a second ECU compared to the parent vehicle, provided that the ECU is only used to control the injectors, additional shut-off valves and the data acquisition from additional sensors.

2.3.2. With regard to requirement (c) and (d): in the case where a demonstration shows two gas- fueled vehicles could be members of the same family with the exception of their certified power output, respectively P_1 and P_2 ($P_1 < P_2$), and both are tested as if were parent vehicles the family relation will be considered valid for any vehicle with a certified power output between 0.7 P_1 and 1.15 P_2.

3.0 GRANTING OF A TYPE APPROVAL

Type approval is granted subject to the following requirements:

3.1. **Exhaust Emissions Approval of a Parent Vehicle**

3.1.1. The parent vehicle should demonstrate its capability to adapt to any fuel composition that may occur across the market. In the case of LPG there are variations in C_3/C_4 composition. In the case of NG/biomethane there are generally two types of fuel, high calorific fuel (H-gas) and low calorific fuel (L-gas), but with a significant spread within both ranges; they differ significantly in Wobbe index. These variations are reflected in the reference fuels.

3.1.2. In the case of vehicles fueled by LPG, NG/biomethane, the parent vehicle(s) shall be tested in the Type I test on the two extreme reference fuels as specified in the applicable Gazette Notification. In the case of NG/biomethane, if the transition from one fuel to another is in practice aided through the use of a switch, this switch shall not be used during type approval. In such a case on the manufacturer's request and with the agreement of the Test Agency the pre-conditioning cycle referred in clause 6.10 of Chapter 3 to this Part may be extended.

3.1.3. The vehicle is considered to conform if, under the tests and reference fuels mentioned in clause 3.1.2 of this Chapter, the vehicle complies with the emission limits.

3.1.4. In the case of vehicles fueled by LPG or NG/biomethane, the ratio of emission results ‘r’ shall be determined for each pollutant as follows:

Type(s) of fuel	Reference fuels	Calculation of "r"
LPG and Gasoline (Approval B)	Fuel A	r = B/A
or LPG only (Approval D)	Fuel B	
NG/bio methane and gasoline (Approval B)	Fuel G_{20}	$R=G_{25}/G_{20}$
Or NG/bio methane only (Approval D)	Fuel G_{25}	

3.2. **Exhaust Emissions Approval of a Member of the Family**:

For the type approval of a mono fuel gas vehicle and bi fuel gas vehicles operating in gas mode, fueled by LPG or NG/Biomethane, as a member of the family, a Type I test shall be performed with one gas reference fuel. This reference fuel may be either of the gas reference fuels. The vehicle is considered to comply if the following requirements are met:

3.2.1. The vehicle complies with the definition of a family member as defined in clause 2.3 of this Chapter;

3.2.2. If the test fuel is reference fuel A for LPG or G_{20} for NG/biomethane, the emission result shall be multiplied by the relevant factor ‘r’ calculated in clause 3.1.4 of this Chapter if r > 1; if r < 1, no correction is needed;

3.2.3. If the test fuel is reference fuel B for LPG or G25 for NG/biomethane, the emission result shall be divided by the relevant factor ‘r’ calculated in clause 3.1.4 of this Chapter if r < 1; if r > 1, no correction is needed;

3.2.4. On the manufacturer's request, the Type I test may be performed on both reference fuels, so that no correction is needed;

3.2.5. The vehicle shall comply with the emission limits valid for the relevant category for both measured and calculated emissions;

3.2.6. If repeated tests are made on the same engine the results on reference fuel G_{20}, or A, and those on reference fuel G_{25}, or B, shall first be averaged; the 'r' factor shall then be calculated from these averaged results;

3.2.7. Without prejudice to clause 6.11.1.3 of Chapter 3 to this Part, during the Type I test it is permissible to use gasoline only or simultaneously with gas when operating in gas mode provided that the energy consumption of gas is higher than 80% of the total amount of energy consumed during the test. This percentage shall be calculated in accordance with the method set out below for (LPG) or (NG/biomethane) in this Chapter.

4.0 GENERAL CONDITIONS

4.1. Tests for conformity of production may be performed with a commercial fuel of which the C_3/C_4 ratio lies between those of the reference fuels in the case of LPG, or of which the Wobbe index lies between those of the extreme reference fuels in the case of NG/biomethane. In that case a fuel analysis needs to be present.

CHAPTER 13 - APPENDIX 1

BI-FUEL GAS VEHICLE-
CALCULATION OF LPG ENERGY RATIO

1.0 MEASUREMENT OF THE LPG MASS CONSUMED DURING THE TYPE I TEST CYCLE

Measurement of the LPG mass consumed during the Type I test cycle shall be done by a fuel weighing system capable of measuring the weight of the LPG storage container during the test in accordance with the following:

An accuracy of ± 2% of the difference between the readings at the beginning and at the end of the test or better.

Precautions shall be taken to avoid measurement errors.

Such precautions shall at least include the careful installation of the device according to the instrument manufacturers' recommendations and to good engineering practice.

Other measurement methods are permitted if an equivalent accuracy can be demonstrated

2.0 CALCULATION OF THE LPG ENERGY RATIO

The fuel consumption value shall be calculated from the emissions of hydrocarbons, carbon monoxide, and carbon dioxide determined from the measurement results assuming that only LPG is burned during the test.

The LPG ratio of the energy consumed in the cycle is then determined as follows:

$$G_{LPG} = M_{LPG} * 10000/(FC_{norm} * dist * d)$$

Where :

G_{LPG} = LPG energy ratio (%);

M_{LPG} = LPG mass consumed during the cycle (kg);

FC_{norm} = fuel consumption (l/100 km) calculated in accordance with clause 7 (b), of Chapter 3 to this Part. If applicable, the correction factor cf in the equation used to determine FC_{norm} shall be calculated using the H/C ratio of the gaseous fuel;

dist = distance travelled during the cycle (km);

d = density d = 0.538 kg/litre.

CHAPTER 13 – APPENDIX 2

BI-FUEL VEHICLE – CALCULATION OF NG/BIOMETHANE ENERGY RATIO

1.0 MEASUREMENT OF THE CNG MASS CONSUMED DURING THE TYPE I TEST CYCLE

Measurement of the CNG mass consumed during the cycle shall be done by a fuel weighing system capable to measure the CNG storage container during the test in accordance with the following:

An accuracy of ± 2% of the difference between the readings at the beginning and at the end of the test or better.

Precautions shall be taken to avoid measurement errors.

Such precautions shall at least include the careful installation of the device according to the instrument manufacturers' recommendations and to good engineering practice.

Other measurement methods are permitted if an equivalent accuracy can be demonstrated.

2.0 CALCULATION OF THE CNG ENERGY RATIO

The fuel consumption value shall be calculated from the emissions of hydrocarbons, carbon monoxide, and carbon dioxide determined from the measurement results assuming that only CNG is burned during the test.

The CNG ratio of the energy consumed in the cycle is then determined as follows:

G_{CNG} = M_{CNG} * cf * 10000/(FC_{norm} * dist * d)

Where :

G_{CNG} = CNG energy ratio (%);

M_{CNG} = CNG mass consumed during the cycle (kg);

FC_{norm} = fuel consumption (m^3/100 km) calculated in accordance with clause 7 (c), of Chapter 3 to this Part.

dist = distance travelled during the cycle (km);

d = density d = 0.654 kg/m^3;

cf = correction factor, assuming the following values:

cf = 1 in case of G_{20} reference fuel;

cf = 0.78 in case of G_{25} reference fuel

CHAPTER 14

ON-BOARD DIAGNOSTICS (OBD) FOR MOTOR VEHICLES

1.0 INTRODUCTION

This Chapter applies to the functional aspects of On-Board Diagnostic (OBD) system for the emission control of motor vehicles.

2.0. DEFINITIONS

For the purposes of this Chapter only:

2.1. **"OBD"** means an on-board diagnostic system for emission control which shall have the capability of identifying the likely area of malfunction by means of fault codes stored in computer memory.

2.2. **"Vehicle type"** means a category of power-driven vehicles which do not differ in such essential engine and OBD system characteristics.

2.3. **"Vehicle family"** means a manufacturer's grouping of vehicles which, through their design, are expected to have similar exhaust emission and OBD system characteristics. Each vehicle of this family shall have complied with the requirements of this Part as defined in Appendix 2 to this Chapter.

2.4. "**Emission control system"** means the electronic engine management controller and any emission related component in the exhaust or evaporative system which supplies an input to or receives an output from this controller.

2.5. **"Malfunction indicator (MI)"** means a visible or audible indicator that clearly informs the driver of the vehicle in the event of a malfunction of any emission-related component connected to the OBD system, or the OBD system itself.

2.6. "**Malfunction"** means the failure of an emission-related component or system that would result in emissions exceeding the limits in clause 3.3.2. of this Chapter or if the OBD system is unable to fulfil the basic conformity requirements of this chapter.

2.7. **"Secondary air"** refers to air introduced into the exhaust system by means of a pump or aspirator valve or other means that is intended to aid in the oxidation of HC and CO contained in the exhaust gas stream.

2.8. **"Engine misfire"** means lack of combustion in the cylinder of a positive ignition engine due to absence of spark, poor fuel metering, poor compression or any other cause. In terms of OBD monitoring it is that percentage of misfires out of a total number of fringe events (as declared by the manufacturer) that would result in emissions exceeding the limits given in clause 3.3.2 of this Chapter or

that percentage that could lead to an exhaust catalyst, or catalysts, overheating causing irreversible damage.

2.9. **"Type I Test"** means the driving cycle (Parts One and Two) used for emission approvals as described in Table 2 and Table 3 of Chapter 3 of this Part.

2.10. A **"driving cycle"** consists of engine key-on, driving mode where a malfunction would be detected if present, and engines key-off.

2.11. A **"warm-up cycle"** means sufficient vehicle operation such that the coolant temperature has risen by at least 22K from engine starting and reaches a minimum temperature of 343K(70°C).

2.12. A **"Fuel trim"** refers to feedback adjustments to the base fuel schedule. Short term fuel trim refers to dynamic or instantaneous adjustments. Long term fuel trim refers to much more gradual adjustments to the fuel calibration schedule than short-term trim adjustments. These long term adjustments compensate for vehicle differences and gradual changes that occur over time.

2.13. A **"Calculated load value"** refers to an indication of the current air flow divided by peak airflow, where peak air flow is corrected or altitude, if available. This definition provides a dimension less number that is not engine specific and provides the service technician with an indication of the proportion of engine capacity that is being used (with wide open throttle as 100%);

$$CLV = \frac{\text{current airflow}}{\text{peak airflow (at sea level)}} \cdot \frac{\text{atmospheric pressure (at sea level)}}{\text{barometric pressure}}$$

2.14. **"Permanent emission default mode"** refers to a case where the engine management controller permanently switches to a setting that does not require an input from a failed component or system where such a failed component or system would result in an increase in emissions from the vehicle to a level above thel imits given in clause 3.3.2 of this Chapter.

2.15. **"Power take-off unit"**means an engine-driven output provision for the purposes of powering auxiliary, vehicle mounted, equipment.

2.16. **"Access"** means the availability of all emission–related OBD data including all fault codes required for the inspection, diagnosis, servicing or repair of emissions-related parts of the vehicle, via the serial interface for the standard diagnostic connection (pursuant to clause 6.5.3.5 of Appendix 1 to this Chapter).

2.17. **"Unrestricted"** means:

2.17.1. Access not dependent on an access code obtainable only from the manufacturer, or a similar device; or

2.17.2. Access allowing evaluation of the data produced without the need for any unique decoding information, unless that information itself is standardised.

2.18. **"Standardised"** means that all data stream information, including all fault codes used, shall be produced only in accordance with industry standards which, by virtue of the fact that their format and their permitted options are clearly defined provide for a maximum level of harmonisation in the motor vehicle industry, and whose use is expressly permitted in this Part.

2.19. **"Repair information"** means all information required for diagnosis, servicing, inspection, periodic monitoring or repair of the vehicle and which the manufacturers provide for their authorised dealers/repair shops. Where necessary, such information shall include service handbooks, technical manuals, diagnosis information (e.g.minimum and maximum theoretical values for measurements), wiring diagrams, the software calibration identification number applicable to a vehicle type,instructions for individual and special cases, information provided concerning tool sand equipment, data record information and two-directional conformity and test data. The manufacturer shall not be obliged to make available that information which is covered by intellectual property rights or constitutes specific know-how of manufacturers and or OEM suppliers; in this case the necessary technical information shall not be improperly withheld.

2.20. **"Deficiency"** means, in respect of vehicle OBD systems, that up to two separate components or systems that are monitored contain temporary or permanent operating characteristics that impair the otherwise efficient OBD monitoring of those components or systems or do not meet all of the other detailed requirements for OBD. Vehicles may be type- approved, registered and sold with such deficiencies according to the requirements of clause 4 of this Chapter.

3.0 REQUIREMENTS AND TESTS

3.1. All vehicles shall be equipped with an OBD system so designed, constructed and installed in a vehicle as to enable it to identify types of deterioration normal function over the entire life of the vehicle. In achieving this objective the Test Agency shall accept that vehicles which have travelled distances in excess of the TypeV durability distance (according to Chapter 12 of this Part) referred to in clause 3.3.1 of this Chapter, may show some deterioration in OBD system performance such that the emission limits given in clause 3.3.2 of this Chapter may be exceeded before the OBD system signals a failure to the driver of the vehicle.

3.1.1. Access to the OBD system required for the inspection, diagnosis, serviceing or repair of the vehicle shall be unrestricted and standardised. All emission related fault codes shall be consistent with clause 6.5.3.4. of Appendix 1 of this Chapter.

3.1.2. No later than three months after the manufacturer has provided any authorised dealer or repairs hop with repair information, the manufacturer shall make that information (including all subsequent amendments and supplements) available upon reasonable and non-discriminatory payment and shall notify the Test Agency accordingly.

In the even to failure to comply with these provisions the Test Agency shall act to ensure that repair information is available, in accordance with the procedures laid down for type approval and in-service surveys.

3.2. The OBD system shall be so designed, constructed and installed in a vehicle as to enable it to comply with the requirements of this Chapter during conditions of normal use.

3.2.1. Temporary Disablement of the OBD System

3.2.1.1. A manufacturer may disable the OBD system if its ability to monitor is affected by low fuel levels. Disablement shall not occur when the fuel tank level is above 20% of the nominal capacity of the fuel tank.

3.2.1.2. A manufacturer may disable the OBD system at ambient engine starting temperatures below 266K (-7°C) or at elevations over 2,500 metres above seal level provided the manufacturer submits data and/ or an engineering evaluation which adequately demonstrate that monitoring would be unreliable when such conditions exist. A manufacturer may also request disablement of the OBD system at other ambient engine starting temperatures if he demonstrates to the Test Agency with data and /or an engineering evaluation that misdiagnosis would occur under such conditions. It is not necessary to illuminate the Malfunction Indicator (MI) if the OBD thresholds are exceeded during a regeneration provided no defect is present.

3.2.1.3. For vehicles designed to accommodate the installation of power take off units, disablement of affected monitoring systems is permitted provided disablement occurs only when the power take-off unit is active.

In addition to the provisions of this clause the manufacturer may temporarily disable the OBD system in the following conditions:

(a) For flex fuel or mono/bi-fuel gas vehicles during 1 minute after refueling to allow for the recognition of fuel quality and composition by the ECU;

(b) For bi-fuel vehicles during 5 seconds after fuel switching to allow for readjusting engine parameters;

(c) The manufacturer may deviate from these time limits if it can demonstrate that stabilization of the fueling system after re-fuelling or fuel switching takes longer for justified technical reasons. In any case, the OBD system shall be re-enabled as soon as either the fuel quality or composition is recognized or the engine parameters are readjusted.

3.2.2. Engine Misfire in Vehicles Equipped with Positive-Ignition Engines

3.2.2.1. Manufacturers may adopt higher misfire percentage malfunction criteria than those declared to the Test Agency, under specific engine speed and load conditions where it can be demonstrated to the Test Agency that the detection of lower levels of misfire would be unreliable.

3.2.2.2. When a manufacturer can demonstrate to the Test Agency that the detection of higher levels of misfire percentages is still not feasible, or that misfire cannot be distinguished from other effect (e.g. rough roads, transmission shifts, after engine starting; etc.) the misfire monitoring system may be disabled when such conditions exist.

3.2.3. Identification of deterioration or malfunctions may be also be done outside a driving cycle (e.g. after engine shutdown).

3.3. Description of Tests

3.3.1. The tests are carried out on the vehicle used for the Type V durability test given in Chapter 12 of this Part and using the test procedure in Appendix 1 to this Chapter. Tests are carried out at the conclusion of the Type V durability testing.

When no Type V durability testing is carried out, or at the request of the manufacturer, a suitably aged and representative vehicle may be used for these OBD demonstration tests.

3.3.2. The OBD system shall indicate the failure of an emission-related component or system when that failure results in emissions exceeding the threshold limits defined in said Gazette Notification:

3.3.3. Monitoring requirements for vehicles equipped with positive-ignition engines;

In satisfying the requirements of clause 3.3.2. of this Chapter the OBD system shall, at a minimum, monitor for:

3.3.3.1. The reduction in the efficiency of the catalytic converter with respect to emissions of NMHC and NO_x. Manufacturers may monitor the front catalyst alone or in combination with the next catalyst(s) downstream. Each monitored catalyst or catalyst combination shall be considered malfunctioning when the emissions exceed the NMHC or NO_x threshold limits defined in said Gazette Notification.

3.3.3.2. The presence of engine misfire in the engine operating region bounded by the following lines:

(a) A maximum speed of 4,500 min^{-1} or 1,000 min^{-1} greater than the highest speed occurring during a Type I Test cycle, whichever is the lower;

(b) The positive torque line (i.e. engine load with the transmission in neutral);

(c) A line joining the following engine operating points: the positive torque line at 3,000 min^{-1} and a point on the maximum speed line defined in (a) above with the engine's manifold vacuum at 13.33 kPa lower than that at the positive torque line.

3.3.3.3 **Oxygen Sensor Deterioration**

This clause shall mean that the deterioration of all oxygen sensors fitted and used for monitoring malfunctions of the catalytic converter according to the requirements of this Chapter shall be monitored.

3.3.3.4. If active on the selected fuel, other emission control system components or systems, or emission related powertrain components or systems which are connected to a computer, the failure of which may result in tail pipe emissions exceeding the limits given in clause 3.3.2 of this Chapter;

3.3.3.5. Unless otherwise monitored, any other emission-related power-train component connected to a computer, including any relevant sensors to enable monitoring functions to be carried out, shall be monitored for circuit continuity;

3.3.3.6. The electronic evaporative emission purge control shall, at a minimum, be monitored for circuit continuity.

3.3.3.7. For direct injection positive ignition engines any malfunction, which may lead to emissions exceeding the particulate threshold limits provided for by clause 3.3.2.of this Chapter and which has to be monitored according to the requirements of this Chapter for compression ignition engines, shall be monitored.

3.3.4. Monitoring Requirements for Vehicles Equipped with Compression-Ignition Engines

In satisfying the requirements of clause 3.3.2.of this chapter the OBD system shall monitor:

3.3.4.1. Where fitted, reduction in the efficiency of the catalytic converter;

3.3.4.2. Where fitted, the functionality and integrity of the particulate trap;

3.3.4.3. The fuel-injection system electronic fuel quantity and timing actuator(s) is/are monitored for circuit continuity and total functional failure;

3.3.4.4. Other emission control system components or systems, or emission-related power train components or systems, which are connected to a computer, the failure of which may result in exhaust emissions exceeding the limits given in clause 3.3.2.of this Chapter. Examples of such systems or components are those for monitoring and control of air mass-flow, air volumetric flow (and temperature), boost pressure and inlet manifold pressure (and relevant sensors to enable these functions to be carried out).

3.3.4.5. Unless otherwise monitored, any other emission-related powertrain component connected to a computer shall be monitored for circuit continuity.

3.3.4.6. Malfunctions and the reduction in efficiency of the EGR system shall be monitored.

3.3.4.7. Malfunctions and the reduction in efficiency of a NO_x after- treatment system using a reagent and the reagent dosing sub-system shall be monitored.

3.3.4.8. Malfunctions and the reduction in efficiency of NO_x after-treatment not using a reagent shall be monitored.

3.3.5. Manufacturers may demonstrate to the Test Agency that certain components or systems need not be monitored if, in the event of their total failure or removal, emissions do not exceed the emission limits given in clause 3.3.2. of this Chapter

3.3.5.1. The following devices should however be monitored for total failure or removal (if removal would cause the applicable emission limits to be exceeded):

(a) A particulate trap fitted to compression ignition engines as a separate unit or integrated into a combined emission control device;

(b) A NOx after-treatment system fitted to compression ignition engines as a separate unit or integrated into a combined emission control device;

(c) A Diesel Oxidation Catalyst (DOC) fitted to compression ignition engines as a separate unit or integrated into a combined emission control device.

3.3.5.2. The devices referred to clause 3.3.5.1 of this Chapter shall also be monitored for any failure that would result in exceeding the applicable OBD threshold limits.

3.4 A sequence of diagnostic checks shall be initiated at each engine start and completed at least once provided that the correct test conditions are met. The test conditions shall be selected in such a way that they all occur under normal driving as represented by the Type I Test.

3.5 Activation of Malfunction Indicator (MI)

3.5.1. The OBD system shall incorporate a malfunction indicator readily perceivable to the vehicle operator. The MI shall not be used for any other purpose except to indicate emergency start-up or limp-home routines to the driver. The MI shall be visible in all reasonable lighting conditions. When activated, it shall display a symbol in conformity with ISO 2575. A vehicle shall not be equipped with more than one general purpose MI for emission related problems. Separate specific purpose tell tales (e.g. brake system, fasten seat belt, oil pressure, etc.) are permitted. The use of red colour for an MI is prohibited.

3.5.2 For strategies requiring more than two preconditioning cycles for MI activation, the manufacturer must provide data and/or an engineering evaluation which adequately demonstrates that the monitoring system is equally effective and timely in detecting component deterioration. Strategies requiring on average more than ten driving cycles for MI activation are not accepted. The MI shall also activate whenever the engine control enters a permanent emission default mode of operation if the emission limits given in clause 3.3.2. of this Chapter are exceeded or if the OBD system is unable to fulfil the basic monitoring requirements specified in clause 3.3.3. or 3.3.4. of this Chapter. The MI shall operate in a distinct warning mode, e.g. a flashing light, under any period during which engine misfire occurs at a level likely to cause catalyst damage, as specified by the manufacturer. The MI shall also activate when the vehicle's ignition is in the "key-on" position before engine starting or cranking and de-activate after engine starting if no malfunction has previously been detected.

3.6 Fault Code Storage

3.6.1. The OBD system must record fault cod (s) indicating the status of the emission control system. Separate status codes must be used to identify correctly functioning emission control systems and those emission control systems which need further vehicle operation to be fully evaluated. If the MI is activated due to deterioration or malfunction or permanent emission default modes of operation, a fault code must be stored that identifies the type of malfunction. A fault code must also be stored in the cases referred to in clauses 3.3.3.5 and 3.3.4.5 of this Chapter.

3.6.2. The distance travelled by the vehicle while the MI is activated shall be available at any instant through the serial port on the standard link connector.

3.6.3. In the case of vehicles equipped with positive ignition engines, misfiring cylinders need not be uniquely identified if a distinct single or multiple cylinder misfire fault code is stored.

3.7 Extinguishing the MI

3.7.1. If misfire at levels likely to cause catalyst damage (as specified by the manufacturer) is not present any more, or if the engine is operated after changes to speed and load conditions where the level of misfire will not cause catalyst damage, the MI may be switched back to the previous state of activation during the first driving cycle on which the misfire level was detected and may be switched to the normal activated mode on subsequent driving cycles. If the MI is switched back to the previous state of activation, the corresponding fault codes and stored freeze-frame conditions may be erased.

3.7.2. For all other malfunctions, the MI may be deactivated after three subsequent sequential driving cycles during which the monitoring system responsible for activating the MI ceases to detect the malfunction and if no other malfunction has been identified that would independently activate the MI.

3.8 Erasing a Fault Code

3.8.1. The OBD system may erase a fault code and the distance travelled and freeze-frame information if the same fault is not re-registered in at least 40 engine warm-up cycles or forty driving cycles with vehicle operation in which the criteria specified in clause 7.5.1.(a)–(c) of Appendix 1 of this Chapter are met.

3.9 Bi-Fuelled Gas Vehicles

In general, for bi-fuelled gas vehicles for each of the fuel types (gasoline and (NG/biomethane)/ LPG)) all the OBD requirements as for a mono-fuelled vehicle are applicable. To this end one of the following two options in clauses 3.9.1 or 3.9.2 of this Chapter or any combination thereof shall be used.

3.9.1. **One OBD System for Both Fuel Types.**

3.9.1.1. The following procedures shall be executed for each diagnostic in a single OBD system for operation on gasoline and on (NG/biomethane)/LPG, either independent of the fuel currently in use or fuel type specific:

(a) Activation of malfunction indicator (MI) (see clause 3.5 of this Chapter);

(b) Fault code storage (see clause 3.6 of this Chapter);

(c) Extinguishing the MI (see clause 3.7of this Chapter);

(d) Erasing a fault code (see clause 3.8 of this Chapter).

For components or systems to be monitored, either separate dignostics for each fuel type can be used or a common diagnostic.

3.9.1.2. The OBD system can reside in either one or more computers.

3.9.2. Two separate OBD systems, one for each fuel type.

3.9.2.1. The following procedures shall be executed independently of each other when the vehicle is operated on gasoline or on (NG/biomethane)/LPG:

(a) Activation of malfunction indicator (MI) (see clause 3.5.of this Chapter);

(b) Fault code storage (see clause 3.6.of this Chapter);

(c) Extinguishing the MI (see clause 3.7.of this Chapter);

(d) Erasing a fault code (see clause 3.8.of this Chapter).

3.9.2.2. The separate OBD systems can reside in either one or more computers.

3.9.3. Specific requirements regarding the transmission of diagnostic signals from bi-fuelled gas vehicles.

3.9.3.1. On a request from a diagnostic scan tool, the diagnostic signals shall be transmitted on one or more source addresses. The use of source addresses is described in the standard listed in clause 6.5.3.2.(a) of Appendix 1 of Chapter 14 of this Part

3.9.3.2. Identification of fuel specific information can be realized:

(a) By use of source addresses; and /or

(b) By use of a fuel selects witch; and /or

(c) By use of fuel specific fault codes.

3.9.4. Regarding the status cod (as described in clause 3.6 of this Chapter), one of the following two options has to be used, if one or more of the diagnostics reporting readiness is fuel type specific:

(a) The status code is fuel specific, i.e. use of two status codes, one for each fuel type;

(b) The status code shall indicate fully evaluated control systems for both fuel types (gasoline and (NG/biomethane) /LPG)) when the control systems are fully evaluated for one of the fuel types.

If none of the diagnostics reporting readiness is fuel type specific, then only one status code has to be supported.

3.10. Additional provisions for vehicles employing engine shut - off strategies

3.10.1 Driving cycle

3.10.1.1. Autonomous engine restarts commanded by the engine control system following an engine stall may be considered a new driving cycle or a continuation of the existing driving cycle.

4.0 REQUIREMENTS RELATING TO THE TYPE-APPROVAL OF ON-BOARD DIAGNOSTIC SYSTEMS

4.1. A manufacturer may request to the Test Agency that an OBD system be accepted for type-approval even though the system contains one or more deficiencies such that the specific requirements of this Chapter are not fully met.

4.2. In considering the request, the Test Agency shall determine whether compliance with the requirements of this chapter is infeasible or unreasonable.

The Test Agency shall take into consideration data from the manufacturer that details such factors as, but not limited to, technical feasibility, lead time and production cycles including phase-in or phase-out of engines or vehicle designs and programmed upgrades of computers, the extent to which the resultant OBD system will be effective in complying with the requirements of this Part and that the manufacturer has demonstrated an acceptable level of effort towards compliance with the requirements of this Part.

4.2.1. The Test Agency will not accept any deficiency request that includes the complete lack of a required diagnostic monitor.

4.2.2. The Test Agency will not accept any deficiency request that does not respect the OBD threshold limits defined in said Gazette Notification.

4.3. In determining the identified order of deficiencies, deficiencies relating to clauses 3.3.3.1, 3.3.3.2 and 3.3.3.3 of this Chapter for positive-ignition engines and clauses 3.3.4.1, 3.3.4.2 and 3.3.4.3 of this Chapter for compression-ignition engines shall be identified first.

4.4. Prior to or at the time of type approval, no deficiency shall be granted in respect of the requirements of clause 6.5., except clause 6.5.3.4.of Appendix 1 of this Chapter.

4.5. Deficiency Period

4.5.1. A deficiency may be carried- over for a period of two years after the date of type-approval of the vehicle type unless it can be adequately demonstrated that substantial vehicle hardware modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-over for a period not exceeding three years.

4.5.2. A manufacturer may request that the Test Agency grant a deficiency retrospectively when such a deficiency is discovered after the original type approval. In this case, the deficiency may be carried-over for a period of two years after the date of notification to the Test Agency unless it can be adequately demonstrated that substantial vehicle hardware modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-over for a period not exceeding three years.

5.0 ACCESS TO OBD INFORMATION

5.1. Applications for type-approval or amendment of a type-approval shall be accompanied by the relevant information concerning the vehicle OBD system. This relevant information shall enable manufacturers of replacement or retrofit components to make the parts they manufacturer compatible with the vehicle OBD system with a view to fault-free operation assuring the vehicle user against malfunctions. Similarly, such relevant information shall enable the manufacturers of diagnostic tool sand test equipment to make tools and equipment that provide for effective and accurate diagnosis of vehicle emission control systems.

5.2. Upon request, the Test Agency shall make the relevant information on the OBD system available to any interested components, diagnostic tools or test equipment manufacturer on a non-discriminatory basis.

5.2.1. If Test Agency receives a request from any interested components, diagnostic tools or test equipment manufacturer for information on the OBD system of a vehicle that has been type-approvedas per AIS-137 and its Parts.

(a) The Test Agency shall, within 30 days, request the manufacturer of the vehicle in question the type to make available the information required.

(b) The manufacturer shall submit this information to the Test Agency within two months of the request;

This requirement shall not invalidate any approval previously granted pursuant to this Part nor prevent extensions to such approvals under the terms of this Part under which they were originally granted.

5.2.2. Information can only be requested for replacement or service components that are subject to this type-approval, or for components that form part of a system that is subject to this type-approval.

5.2.3. The request for information must identify the exact specification of the vehicle model for which the information is required. It must confirm that the information is required for the development of replacement or retrofit parts or components or diagnostic tools or test equipment.

CHAPTER 14 – APPENDIX 1

FUNCTIONAL ASPECTS OF ON-BOARD DIAGNOSTIC (OBD) SYSTEMS

1.0 INTRODUCTION

This Appendix describes the procedure of the test according to clause 3 of this Chapter. The procedure describes a method for checking the function of the On-Board Diagnostic (OBD) system installed on the vehicle by failure simulation of relevant systems in the engine management or emission control system. It also sets procedures for determining the durability of OBD systems.

The manufacturer shall make available the defective components and/or electrical devices which would be used to simulate failures. When measured over the Type I Test cycle, such defective components or devices shall not cause the vehicle emissions to exceed the limits defined in said Gazette Notification by more than 20%. For electrical failures (short/open circuit), the emissions may exceed the relevant OBD limits by more than 20%.

When the vehicle is tested with the defective component or device fitted, the OBD system is approved if the MI is activated. The OBD system is also approved if the MI is activated below the OBD threshold limits.

2.0 DESCRIPTION OF TEST

2.1. The testing of OBD systems consists of the following phases:

2.1.1. Simulation of malfunction of a component of the engine management or emission control system,

2.1.2. Preconditioning of the vehicle with a simulated malfunction over preconditioning specified in clause 6.2.1 or clause 6.2.2 of this Appendix.

2.1.3. Driving the vehicle with a simulated malfunction over the Type I Test cycle and measuring the emissions of the vehicle,

2.1.4. Determining whether the OBD system reacts to the simulated malfunction and indicates malfunction in an appropriate manner to the vehicle driver.

2.2. Alternatively, at the request of the manufacturer, malfunction of one or more components may be electronically simulated according to the requirements of clause 6 of this Appendix.

2.3. Manufacturers may request that monitoring take place outside the Type I Test cycle if it can be demonstrated to the Test Agency that conformity during conditions encountered during the Type I Test cycle would impose restrictive monitoring conditions when the vehicle is used in service.

3.0 TEST VEHICLE AND FUEL

3.1. **Vehicle**

The test vehicle shall meet the requirements of clause 2.2 of Chapter 3 of this Part.

3.2. **Fuel**

The appropriate reference fuel for gasoline, diesel, LPG and NG fuels must be used for testing. The fuel type for each failure mode to be tested (described in clause 6.3. of this Appendix) may be selected by the Test Agency from the reference fuels in the case of the testing of a mono-fuelled and bi-fuelled vehicle. The selected fuel type must not be changed during any of the test phases described in clause 2.1 to 2.3 of this Appendix. In the case of the use of LPG or NG / biomethane as a fuel it is permissible that the engine is started on gasoline and switched to LPG or NG/biomethane after a pre-determined period of time which is controlled automatically and not under the control of the driver.

4.0 TEST TEMPERATURE AND PRESSURE

4.1. The test temperature and pressure shall meet the requirements of the Type I Test as described in clause 2.1 of Chapter 3 of this Part.

5.0 TEST EQUIPMENT

5.1. **Chassis Dynamometer**

The chassis dynamometer shall meet the requirements of Appendix 1 of Chapter 4 of this Part .

6.0 OBD TEST PROCEDURE

6.1. The operating cycle on the chassis dynamometer shall meet the requirements of Chapter 3 to this Part.

6.1.1. The Type I test need not be performed for the demonstration of electrical failures (short/open circuit). The manufacturer may demonstrate these failure modes using driving conditions in which the component is used and the monitoring conditions are encountered. These conditions shall be documented in the type approval documentation.

6.2. **Vehicle Preconditioning**

6.2.1. According to the engine type and after introduction of one of the failure modes given in clause 6.3 of this Appendix, the vehicle shall be preconditioned by driving at least two consecutive Type I Tests (Parts One and Two). For compression-ignition engined vehicles an additional preconditioning of two Part Two cycles is permitted.

6.2.2. At the request of the manufacturer, alternative preconditioning methods may be used.

6.2.3 The use of additional preconditioning cycles or alternative preconditioning methods shall be documented in the type approval documentation.

6.3. Failure Modes to be Tested

6.3.1. Positive-ignition engined vehicles:

6.3.1.1. Replacement of the catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.

6.3.1.2. Engine misfire conditions according to the conditions for misfire monitoring given in clause 3.3.3.2of this Chapter.

6.3.1.3. Replacement of the oxygen sensor with a deteriorated or defective oxygen sensor electronic simulation of such a failure.

6.3.1.4. Electrical disconnection of any other emission-related component connected to a power-train management computer (if active on the selected fuel type).

6.3.1.5. Electrical disconnection of the electronic evaporative purge control device (if equipped and if active on the selected fuel type).

6.3.2. Compression-ignition engine vehicles:

6.3.2.1. Where fitted, replacement of the catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.

6.3.2.2. Where fitted, total removal of the particulate trap or, where sensors are an integral part of the trap, a defective trap assembly.

6.3.2.3. Electrical disconnection of any fueling system electronic fuel quantity and timing actuator.

6.3.2.4. Electrical disconnection of any other emission-related component connected to a power train management computer.

6.3.2.5. In meeting the requirements of clauses 6.3.2.3 and 6.3.2.4 of this Appendix, and with the agreement of the Test Agency, the manufacturer shall take appropriate steps to demonstrate that the OBD system will indicate a fault when disconnection occurs.

6.3.2.6. The manufacturer shall demonstrate that malfunctions of the EGR flow and cooler are detected by the OBD system during its approval test.

6.4. **OBD System Test**

6.4.1. Vehicles fitted with positive-ignition engines:

6.4.1.1 After vehicle preconditioning according to clause 6.2 of this Appendix, the test vehicle is driven over a Type I Test (Parts One and Two).

The MI shall be activated at the latest before the end of this test under any of the conditions given in clauses 6.4.1.2 to 6.4.1.5 of this Appendix, the MI may also be activated during preconditioning. The Test agency may substitute those conditions with others in accordance with clause 6.4.1.6 of this Appendix. However, the total number of failures simulated shall not exceed four (4) Type I Test for the purpose of type approval.

In the case of testing a bi-fuel gas vehicle, both fuel types shall be used within the maximum of four (4) simulated failures at the discretion of the Test Agency.

6.4.1.2. Replacement of a catalyst with a deteriorated or defective catalyst or electronic simulation of a deteriorated or defective catalyst that results in emissions exceeding the NMHC limit given in said notification.

6.4.1.3. An induced misfire condition according to the conditions for misfire monitoring given in Clause 3.3.3.2. of this Chapter that results in emissions exceeding any of the limits given insaid Gazette Notification.

6.4.1.4. Replacement of an oxygen sensor with a deteriorated or defective oxygen sensor or electronic simulation of a deteriorated or defective oxygen sensor that results in emissions exceeding any of the limits given in said Gazette Notification.

6.4.1.5. Electrical disconnection of the electronic evaporative purge control device (if equipped and if active on the selected fuel type).

6.4.1.6. Electrical disconnection of any other emission-related power-train component connected to a computer that results in emissions exceeding any of the limits given in said Gazette Notification. (if active on the selected fuel type).

6.4.2. Vehicles fitted with compression-ignition engines:

6.4.2.1. After vehicle preconditioning according to clause 6.2 of this Appendix, the test vehicle is driven over a Type I Test (Parts One and Two).

The MI shall activate before the end of this test under any of the conditions given in clauses 6.4.2.2 to 6.4.2.5. of this Appendix. The MI may also be activated during preconditioning. The Test Agency may substitute those conditions with others in accordance with clause 6.4.2.5. of this Appendix. However, the total number of failures simulated shall not exceed four (4) Type I Test for the purposes of type approval

6.4.2.2. Where fitted, replacement of a catalyst with a deteriorated or defective catalyst or electronic simulation of a deteriorated or defective catalyst that results in emissions exceeding relevant OBD limits given in said Gazette Notification.

6.4.2.3. Where fitted, total removal of the particulate trap or replacement of the particulate trap with a defective particulate trap meeting the conditions of clause 6.3.2.2. of this Appendix that results in emissions exceeding relevant OBD limits given in said Gazette Notification.

6.4.2.4. With reference to clause 6.3.2.5., of this Appendix, disconnection of any fueling system electronic fuel quantity and timing actuator that results in emissions exceeding relevant OBD limits given in said Gazette Notification.

6.4.2.5. With reference to clause 6.3.2.5., of this Appendix, disconnection of any other emission related power-train component connected to a computer that results in emissions exceeding relevant OBD limits given in said notification

6.5. **Diagnostic Signals**

6.5.1 Reserved

6.5.1.1. Upon determination of the first malfunction of any component or system, “freeze frame” engine conditions present at the time shall be stored in computer memory. Should a subsequent fuel system or misfire malfunction occur, any previously stored freeze-frame conditions shall be replaced by the fuel system or misfire conditions (whichever occurs first). Stored engine conditions shall include, but are not limited to calculated load value, engine speed, fuel trim value(s) (if available), fuel pressure (if available), vehicle speed (if available), coolant temperature, intake manifold pressure (if available),closed- or open-loop operation (if available) and the fault code which caused the data to be stored. The manufacturer shall choose the most appropriate set of conditions facilitating effective repairs for freeze-frame storage. Only one frame of data is required. Manufacturers may choose to store additional frames provided that atleast the required frame can be read by a generic scan tool meeting the specifications of clauses 6.5.3.2. and 6.5.3.3. of this Appendix. If the fault code causing the conditions to be stored is erased in accordance with clause 3.8 of this Chapter, the stored engine conditions may also be erased.

6.5.1.2. If available, the following signals in addition to the required freeze-frame information shall be made available on demand through the serial port on the standardized data link connector, if the information is available to the On-Board computer or can be determined using information available to the on-board computer: diagnostic trouble codes, engine coolant temperature, fuel control system status (closed-loop, open-loop, other), fuel trim, ignition timing advance, intake air temperature, manifold air pressure, air flow rate, engine speed, throttle position sensor output value, secondary air status (upstream, downstream or atmosphere), calculated load value, vehicle speed and fuel pressure.

The signals shall be provided in standard units based on the specifications given in clause 6.5.3. of this Appendix. Actual signals shall be clearly identified separately from default value or limp-home signals.

6.5.1.3. For all emission control systems for which specific on–board evaluation tests are conducted (catalyst, oxygen sensor, etc.), except misfire detection, fuel system monitoring and comprehensive component monitoring, the results of the most recent test performed by the vehicle and the limits to which the system is compared shall be made available through the serial data port on the standardized data link connector according to the specifications given in clause 6.5.3.of this Appendix. For the monitored components and systems excepted above, a pass/fail indication for the most recent test results shall be available through the data link connector.

All data required to be stored in relation to OBD in-use performance according to the provisions of clause 7.6. of this Appendix shall be available through the serial data port on the standardized data link connector according to the specifications given in clause 6.5.3. of this Appendix.

6.5.1.4. The OBD requirements to which the vehicle is certified and the major emission control systems monitored by the OBD system consistent with clause 6.5.3.3. of this Appendix shall be available through the serial data port on the standardized data link connector according to the specifications given in clause 6.5.3. of this Appendix.

6.5.1.5. For all types of vehicles entering into service, the software calibration identification number shall be made available through the serial port on the standardized data link connector. The software calibration identification number shall be provided in a standardized format.

6.5.2. The emission control diagnostic system is not required to evaluate components during malfunction if such evaluation would result in a risk to safety or component failure

6.5.3. The emission control diagnostic system shall provide for standardized and unrestricted access and conform with the following ISO standards and /or SAE specification. Later versions may be used at the manufacturer’s discretion.

6.5.3.1. The following standard shall be used as the on-board to off-board communications link

(a) ISO DIS 15765-4:2011 "Road vehicles – Diagnostics on Controller Area Network (CAN) – Part 4: Requirements for emissions-related systems", dated 1 February 2011.

6.5.3.2 Standards used for the transmission of OBD relevant information

(a) ISO 15031-5 "Road vehicles – communication between vehicles and external test equipment for emissions-related diagnostics – Part 5: Emissions-related diagnostic services", dated 1 April 2011 or SAE J1979 dated 23 February 2012;

(b) ISO 15031-4 "Road vehicles – Communication between vehicle and external test equipment for emissions related diagnostics – Part 4: External test equipment", dated 1 June 2005 or SAE J1978 dated 30 April 2002;

(c) ISO 15031-3 "Road vehicles – Communication between vehicle and external test equipment for emissions related diagnostics Part 3: Diagnostic connector and related electrical circuits: specification and use", dated 1 July 2004 or SAE J 1962 dated 26 July 2012;

(d) ISO 15031-6 "Road vehicles – Communication between vehicle and external test equipment for emissions related diagnostics – Part 6: Diagnostic trouble code definitions", dated 13 August 2010 or SAE J2012 dated 07 March 2013;

(e) ISO 27145 "Road vehicles- Implementation of World-Wide Harmonized On-Board Diagnostics (WWH-OBD)" DT 2012-08-15 with the restriction that only 6.5.3.1 (a) may be used as a data link

(f) ISO 14229:2013 "Road vehicles- Unified diagnostic services (UDS) with the restriction, that only 6.5.3.1 (a) may be used as a data link"

6.5.3.3. Test equipment and diagnostic tools needed to communicate with OBD systems shall meet or exceed the functional specification given in the standard listed in clause 6.5.3.2.(b) of this Appendix.

6.5.3.4. Basic diagnostic data (as specified in clause 6.5.1.1 to 6.5.1.5 of this Appendix), and bi-directional control information shall be provided using the format and units described in the standard listed in clause 6.5.3.2.(a) of this Appendix and must be available using a diagnostic tool meeting the requirements of the standard listed in clause 6.5.3.2.(b) of this Appendix.

The vehicle manufacturer shall provide to a national standardization body the details of any emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in the standard listed in clause 6.5.3.2.(a) of this Appendix but related to this Part.

6.5.3.5 When a fault is registered, the manufacturer shall identify the fault using an appropriate ISO/SAE controlled fault code specified in one of the standards listed in clause 6.5.3.2(d) of this Appendix relating to “emission related system diagnostic trouble codes”. If such identification is not possible, the manufacturer may use manufacturer controlled diagnostic trouble codes according to same standard The fault codes shall be fully accessible by standardized diagnostic equipment complying with the provisions of clause 6.5.3.2. of this Chapter.

The vehicle manufacturer shall provide to a national standardization body the details of any emission-related diagnostic data, e.g. PID’s, OBD monitor Id’s, Test Id’s not specified in the standards listed in clause 6.5.3.2.(a) of this Appendix but related to this Part.

6.5.3.6. The connection interface between the vehicle and the diagnostic tester shall be standardized and shall meet all the requirements of the standard listed in clause 6.5.3.2.(c) of this Appendix. The installation position shall be subject to agreement of the Test Agency such that it is readily accessible by service personnel but protected from tampering by non-qualified personnel.

6.5.3.7. The manufacturer shall also make accessible, where appropriate on payment, the technical information required for the repair or maintenance of motor vehicles unless that information is covered by an intellectual property right or constitutes essential, secret know-how which is identified in an appropriate form; in such case, the necessary technical information shall not be withheld improperly.

Entitled to such information is any person engaged in commercially servicing or repairing, road-side rescuing, inspecting or testing of vehicles or in the manufacturing or selling replacement or retro-fit components, diagnostic tools and test equipment.

7.0 IN-USE PERFORMANCE.

7.1. General Requirements

7.1.1 Each monitor of the OBD system shall be executed at least once per driving cycle in which the monitoring conditions as specified in clause 7.2. of this Appendix are met. Manufacturers may not use the calculated ratio (or any element thereof) or any other indication of monitor frequency as a monitoring condition for any monitor.

7.1.2 The In-Use Performance Ratio (IUPR) of a specific monitor M of the OBD systems and in-use performance of pollution control devices shall be:

$IUPR_M = Numerator_M / Denominator_M$

7.1.3 Comparison of Numerator and Denominator gives an indication of how often a specific monitor is operating relative to vehicle operation. To ensure all manufacturers are tracking $IUPR_M$ in the same manner, detailed requirements are given for defining and incrementing these counters

7.1.4 If, according to the requirements of this Chapter, the vehicle is equipped with a specific monitor M, $IUPR_M$ shall be greater or equal to 0.1 for all monitors M.

7.1.5 Vehicle shall comply with the requirements of clause 7.1.4 of this Appendix for a mileage of at least 160,000km.

7.1.6 The requirements of this clause are deemed to be met for a particular monitor M, if for all vehicles of a particular OBD family manufactured in a particular calendar year the following statistical conditions hold:

(a) The average $IUPR_M$ is equal or above the minimum value applicable to the monitor;

(b) More than 50% of all vehicles have an IUPRM equal or above the minimum value applicable to the monitor.

7.1.7. The manufacturer shall demonstrate to the Test Agencies that these statistical conditions are satisfied all monitors required to be reported by the OBD system according to clause 7.6. of this Appendix not later than 18 months thereafter. For this purpose, for OBD families consisting of more than 1,000 registrations that are subject to sampling within the sampling period, the process described in clause 9. of Chapter 1 of this Part shall be used without prejudice to the provisions of clause 7.1.9. of this Appendix.

In addition to the requirements set out in clause 9. of Chapter 1 of this Part and regardless of the result of the audit described in clause 9.2. of Chapter 1 of this Part, the Test Agency granting the approval shall apply the in-service conformity check for IUPR described in Appendix 1 of Chapter 18 of this Part in an appropriate number of randomly determined cases. "In an appropriate number of randomly determined cases" means that this measure has a dissuasive effect on non- compliance with the requirements of clause 7. of this Appendix or the provision of manipulated, false or non-representative data for the audit. If no special circumstances apply and can be demonstrated by the Test Agency, random application of the in-service conformity check to 5% of the type approved OBD families shall be considered as sufficient for compliance with this requirement. For this purpose, Test Agency may find arrangements with the manufacturer for the reduction of double testing of a given OBD family as long as these arrangements do not harm the dissuasive effect of the Test Agency's own in-service conformity check on non-compliance with the requirements of this clause 7. of this Appendix.

7.1.8. For the entire test sample of vehicles the manufacturer shall report to the relevant Test Agency all of the in-use performance data to be reported by the OBD system according to clause 7.6. of this appendix in conjunction with an identification of the vehicle being tested and the methodology used for the selection of the tested vehicles from the fleet. Upon request, the Test Agency granting the approval shall make these data and the results of the statistical evaluation available to the Nodal Agency.

7.1.9. Public authorities and their delegates may pursue further tests on vehicles or collect appropriate data recorded by vehicles to verify compliance with the requirements of this Chapter.

7.2. **Numerator$_M$**

7.2.1. The numerator of a specific monitor is a counter measuring the number of times a vehicle has been operated such that all conformity conditions necessary for the specific monitor to detect a malfunction in order to warn the driver, as they have been implemented by the manufacturer, have been encountered. The numerator shall not be incremented more than once per driving cycle, unless there is reasoned technical justification.

7.3. **Denominator$_M$**

7.3.1. The purpose of the denominator is to provide a counter indicating the number of vehicle driving events, taking into account special conditions for a specific monitor. The denominator shall be incremented at least once per driving cycle, if during this driving cycle such conditions are met and the general denominator is incremented as specified in clause 7.5. of this Appendix unless the denominator is disabled according to clause 7.7. of this Appendix.

7.3.2. In addition to the requirements of clause 7.3.1. of this Appendix:

(a) Secondary air system monitor denominator(s) shall be incremented if the commanded "on" operation of the secondary air system occurs for a time greater than or equal to 10 seconds. For purposes of determining this commanded "on" time, the OBD system may not include time during intrusive operation of the secondary air system solely for the purposes of monitoring.

(b) Denominators of monitors of systems only active during cold start shall be incremented if the component or strategy is commanded "on" for a time greater than or equal to 10 seconds.

(c) The denominator(s) for monitors of Variable Valve Timing (VVT) and/or control systems shall be incremented if the component is commanded to function (e.g., commanded "on", "open", "closed", "locked", etc.) on two or more occasions during the driving cycle or for a time greater than or equal to 10 seconds, whichever occurs first.

(d) For the following monitors, the denominator(s) shall be incremented by one if, in addition to meeting the requirements of this clause on at least one driving cycle, at least 800 cumulative kilometres of vehicle operation have been experienced since the last time the denominator was incremented.

(i) Diesel oxidation catalyst;

(ii) Diesel particulate filter.

(e) Without prejudice to requirements for the increment of denominators of other monitors the denominators of monitors of the following components shall be incremented if and only if the driving cycle started with a cold start:

(i). Liquid (oil, engine coolant, fuel, SCR reagent) temperature sensors;

(ii). Clean air (ambient air, intake air, charge air, inlet manifold) temperature sensors;

(iii). Exhaust (EGR recirculation/cooling, exhaust gas turbo-charging, catalyst) temperature sensors;

(f) The denominators of monitors of the boost pressure control system shall be incremented if all of the following conditions are met:

(i) The general denominator conditions arc fulfilled;

(ii) The boost pressure control system is active for a time greater than or equal to 15 seconds.

7.3.3. For hybrid vehicles, vehicles that employ alternative engine start hardware or strategies (e.g. integrated starter and generators), or alternative fuel vehicles (e.g. dedicated, bi-fuel, or dual-fuel applications), the manufacturer may request the approval of the Test Agency to use alternative criteria to those set forth in this clause for incrementing the denominator. In general, the Test Agency shall not approve alternative criteria for vehicles that only employ engine shut off at or near idle/vehicle stop conditions. Approval by the Test Agency of the alternative criteria shall be based on the equivalence of the alternative criteria to determine the amount of vehicle operation relative to the measure of conventional vehicle operation in accordance with the criteria in this clause.

7.4. **Ignition Cycle Counter**

7.4.1. The ignition cycle counter indicates the number of ignition cycles a vehicle has experienced. The ignition cycle counter may not be incremented more than once per driving cycle.

7.5. **General Denominator**

7.5.1. The general denominator is a counter measuring the number of times a vehicle has been operated. It shall be incremented within 10 seconds, if and only if, the following criteria are satisfied on a single driving cycle:

(a) Cumulative time since engine start is greater than or equal to 600 seconds while at an elevation of less than 2,440 m above sea level and at an ambient temperature of greater than or equal to -7°C;

(b) Cumulative vehicle operation at or above 40 km/h occurs for greater than or equal to 300 seconds while at an elevation of less than 2,440 m above sea level and at an ambient temperature of greater than or equal to -7°C;

(c) Continuous vehicle operation at idle (i.e. accelerator pedal released by driver and vehicle speed less than or equal to 1.6 km/h) for greater than or equal to 30 seconds while at an elevation of less than 2,440 m above sea level and at an ambient temperature of greater than or equal to -7°C.

7.6. **Reporting and Increasing Counters**

7.6.1. The OBD system shall report in accordance with the ISO 15031-5 specifications of the standard listed in clause 6.5.3.2.(a) of this Appendix, the ignition cycle counter and general denominator as well as separate numerators and denominators for the following monitors, if their presence on the vehicle is required by this Chapter:

(a) Catalysts (each bank to be reported separately);

(b) Oxygen/exhaust gas sensors, including secondary oxygen sensors (each sensor to be reported separately);

(c) Evaporative system;

(d) EGR system;

(e) VVT system;

(f) Secondary air system;

(g) Particulate filter;

(h) NO_x after-treatment system (e.g. NO_x adsorber, NO_x reagent/ catalyst system);

(i) Boost pressure control system.

7.6.2. For specific components or systems that have multiple monitors, which are required to be reported by this point (e.g. oxygen sensor bank 1 may have multiple monitors for sensor response or other sensor characteristics), the OBD system shall separately track numerators and denominators for each of the specific and report only the corresponding numerator and denominator for the specific monitor that has the lowest numerical ratio. If two or more specific monitors have identical ratios, the corresponding numerator and denominator for the specific monitor that has the highest denominator shall be reported for the specific component.

7.6.2.1. Numerators and denominators for specific monitors of components or systems that are monitoring continuously for short circuit or open circuit failures are exempted from reporting.

"Continuously," if used in this context means monitoring is always enabled and sampling of the signal used for monitoring occurs at a rate no less than two samples per second and the presence or the absence of the failure relevant to that monitor has to be concluded within 15 seconds.

If for control purposes, a computer input component is sampled less frequently, the signal of the component may instead be evaluated each time sampling occurs.

It is not required to activate an output component/system for the sole purpose of monitoring that output component/system.

7.6.3. All counters, when incremented, shall be incremented by an integer of one.

7.6.4. The minimum value of each counter is 0, the maximum value shall not be less than 65,535 not withstanding any other requirements on standardized storage and reporting of the OBD system.

7.6.5. If either the numerator or denominator for a specific monitor reaches its maximum value, both counters for that specific monitor shall be divided by two before being incremented again according to the provisions set in clauses 7.2. and 7.3. of this Appendix. If the ignition cycle counter or the general denominator reaches its maximum value, the respective counter shall change to zero at its next increment according to the provisions set in clauses 7.4. and 7.5. of this Appendix, respectively.

7.6.6. Each counter shall be reset to zero only when a non-volatile memory reset occurs (e.g. reprogramming event, etc.) or, if the numbers are stored in keep-alive memory (KAM), when KAM is lost due to an interruption in electrical power to the control module (e.g. battery disconnect, etc.).

7.6.7. The manufacturer shall take measures to ensure that the values of numerator and denominator cannot be reset or modified, except in cases provided for explicitly in this clause.

7.7. **Disablement of Numerators and Denominators and of the General Denominator**

7.7.1. Within 10 seconds of a malfunction being detected, which disables a monitor required to meet the monitoring conditions of this Chapter (i.e. a pending or confirmed code is stored), the OBD system shall disable further incrementing of the corresponding numerator and denominator for each monitor that is disabled. When the malfunction is no longer detected (i.e., the pending code is erased through self-clearing or through a scan tool command), incrementing of all corresponding numerators and denominators shall resume within 10 seconds.

7.7.2. Within 10 seconds of the start of a Power Take-off Operation (PTO) that disables a monitor required to meet the monitoring conditions of this Chapter, the OBD system shall disable further incrementing of the corresponding numerator and denominator for each monitor that is disabled. When the PTO operation ends, incrementing of all corresponding numerators and denominators shall resume within 10 seconds.

7.7.3. The OBD system shall disable further incrementing of the numerator and denominator of a specific monitor within 10 seconds, if a malfunction of any component used to determine the criteria within the definition of the specific monitor's denominator (i.e. vehicle speed, ambient temperature, elevation, idle operation, engine cold start, or time of operation) has been detected and the corresponding pending fault code has been stored. Incrementing of the numerator and denominator shall resume within 10 seconds when the malfunction is no longer present (e.g. pending code erased through self-clearing or by a scan tool command).

7.7.4. The OBD system shall disable further incrementing of the general denominator within 10 seconds, if a malfunction has been detected of any component used to determine whether the criteria in clause 7.5. of this Appendix are satisfied (i.e. vehicle speed, ambient temperature, elevation, idle operation, or time of operation) and the corresponding pending fault code has been stored. The general denominator may not be disabled from incrementing for any other condition. Incrementing of the general denominator shall resume within 10 seconds when the malfunction is no longer present (e.g. pending code erased through self-clearing or by a scan tool command).

CHAPTER 14 – APPENDIX 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE FAMILY

1.0 PARAMETERS DEFINING THE OBD FAMILY

The OBD family means a manufacturer's grouping of vehicles which, through their design, are expected to have similar exhaust emission and OBD system characteristics. Each engine of this family shall comply with the requirements of this Part.

The OBD family may be defined by basic design parameters which shall be common to vehicles within the family. In some cases there may be interaction of parameters. These effects shall also be taken into consideration to ensure that only vehicles with similar exhaust emission characteristics are included within an OBD family.

To this end, those vehicle types whose parameters described below are identical are considered to belong to the same engine/emission control/OBD system combination.

Engine:

(a) Combustion process (i.e. positive ignition, compression-ignition, two-stroke, four-stroke/rotary);

(b) Method of engine fuelling (i.e. single or multi-point fuel injection); and

(c) Fuel type (i.e. gasoline, diesel, flex fuel gasoline/ethanol, flex fuel diesel/biodiesel, NG/biomethane, LPG, bi-fuel gasoline/NG/biomethane, bi-fuel gasoline/LPG).

Emission control system:

(a) Type of catalytic converter (i.e. oxidation, three-way, heated catalyst, SCR, other);

(b) Type of particulate trap;

(c) Secondary air injection (i.e. with or without); and

(d) Exhaust gas recirculation (i.e. with or without);

OBD parts and functioning.

The methods of OBD functional monitoring malfunction detection and malfunction indication to the vehicle driver.

CHAPTER 15

EMISSIONS TEST PROCEDURE FOR A VEHICLE EQUIPPED WITH A PERIODICALLY REGENERATING SYSTEM

1.0 INTRODUCTION

This Chapter defines the specific provisions regarding type-approval of a vehicle equipped with a periodically regenerating system as defined in clause 2.20 of Chapter 1 of this Part.

2.0 SCOPE AND EXTENSION OF THE TYPE APPROVAL

2.1. **Vehicle Family Groups Equipped with Periodically Regenerating System**

The procedure applies to vehicles equipped with a periodically regenerating system as defined in clause 2.20 of Chapter 1 of this Part. For the purpose of this Chapter vehicle family groups may be established. Accordingly, those vehicle types with regenerative systems, whose parameters described below are identical, or within the stated tolerances, shall be considered to belong to the same family with respect to measurements specific to the defined periodically regenerating systems.

2.1.1. Identical parameters are:

Engine:

(a) Combustion process.

Periodically regenerating system (i.e. catalyst, particulate trap):

(a) Construction (i.e. type of enclosure, type of precious metal, type of substrate, cell density);

(b) Type and working principle;

(c) Dosage and additive system;

(d) Volume ±10 percent;

(e) Location (temperature ±50 °C at 90 km/h or 5% difference of maximum temperature/pressure).

2.2. **Vehicle Types of Different Reference Masses**

The K_i factors developed by the procedures in this Chapter for type approval of a vehicle type with a periodically regenerating system as defined in clause 2.20 of Chapter 1 of this Part, may be extended to other vehicles in the family group with a reference mass within the next two higher equivalent inertia classes or any lower equivalent inertia.

3.0 TEST PROCEDURE

The vehicle may be equipped with a switch capable of preventing or permitting the regeneration process provided that this operation has no effect on original engine calibration. This switch shall be permitted only for the purpose of preventing regeneration during loading of the regeneration system and during the pre-conditioning cycles. However, it shall not be used during the measurement of emissions during the regeneration phase; rather the emission test shall be carried out with the unchanged Original Equipment Manufacturers (OEM) control unit.

3.1. **Exhaust Emission Measurement Between Two Cycles where Regenerative Phases Occur**

3.1.1. Average emissions between regeneration phases and during loading of the regenerative device shall be determined from the arithmetic mean of several approximately equidistant (if more than 2) Type I operating cycles or equivalent engine test bench cycles. As an alternative, the manufacturer may provide data to show that the emissions remain constant (±15%) between regeneration phases. In this case, the emissions measured during the regular Type I Test may be used. In any other case emissions measurement for at least two Type I operating cycles or equivalent engine test bench cycles must be completed: one immediately after regeneration (before new loading) and one as close as possible prior to a regeneration phase. All emissions measurements and calculations shall be carried out according to Clause 6.11. to 6.13. of Chapter 3 to this Part. Determination of average emissions for a single regenerative system shall be calculated according to clause 3.3 of this Chapter and for multiple regeneration systems according to clause 3.4 of this Chapter.

3.1.2. The loading process and Ki determination shall be made during the Type I operating cycle, on a chassis dynamometer or on an engine test bench using an equivalent test cycle. These cycles may be run continuously (i.e. without the need to switch the engine off between cycles). After any number of completed cycles, the vehicle may be removed from the chassis dynamometer, and the test continued at a later time.

3.1.3. The number of cycles (D) between two cycles where regeneration phases occur, the number of cycles over which emissions measurements are made (n), and each emissions measurement (M'_{sij}) shall be reported in AIS 007 as applicable.

3.2. **Measurement of Emissions During Regeneration**

3.2.1. Preparation of the vehicle, if required, for the emissions test during a regeneration phase, may be completed using the preparation cycles in Clause 6.10 of Chapter 3 to this Part or equivalent engine test bench cycles, depending on the loading procedure chosen in clause 3.1.2 of this Chapter.

3.2.2. The test and vehicle conditions for the Type I test described in Chapter 3 to this Part apply before the first valid emission test is carried out.

3.2.3. Regeneration must not occur during the preparation of the vehicle. This may be ensured by one of the following methods:

3.2.3.1. A "dummy" regenerating system or partial system may be fitted for the preconditioning cycles.

3.2.3.2. Any other method agreed between the manufacturer and the Test Agency.

3.2.4. A cold-start exhaust emission test including a regeneration process shall be performed according to the Type I operating cycle, or equivalent engine test bench cycle. If the emissions tests between two cycles where regeneration phases occur are carried out on an engine test bench, the emissions test including a regeneration phase shall also be carried out on an engine test bench.

3.2.5. If the regeneration process requires more than one operating cycle, subsequent test cycle(s) shall be driven immediately, without switching the engine off, until complete regeneration has been achieved (each cycle shall be completed). The time necessary to set up a new test should be as short as possible (e.g. particular matter filter change). The engine must be switched off during this period.

3.2.6. The emission values during regeneration (M_{ri}) shall be calculated according to clause 6.13.of Chapter 3 to this Part. The number of operating cycles (d) measured for complete regeneration shall be recorded.

3.3. **Calculation of the Combined Exhaust Emissions of a Single Regenerative System**

$$(1) \quad M_{si} = \frac{\sum_{j=1}^{n} M'_{sij}}{n} \qquad n \geq 2$$

$$(2) \quad M_{ri} = \frac{\sum_{j=1}^{d} M'_{rij}}{d}$$

$$(3) \quad M_{pi} = \left\{ \frac{M_{si} * D + M_{ri} * d}{D + d} \right\}$$

Where for each pollutant (i) considered:

M'_{sij} = mass emissions of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) without regeneration,

M'_{rij} = mass emissions of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) during regeneration (if d > 1, the first Type I test is run cold, and subsequent cycles are hot),

M_{si} = mass emissions of pollutant (i) in g/km without regeneration,

M_{ri} = mass emissions of pollutant (i) in g/km during regeneration,

M_{pi} = mass emissions of pollutant (i) in g/km,

n = number of test points at which emissions measurements (Type I operating cycles or equivalent engine test bench cycles) are made between two cycles where regenerative phases occur, ≥ 2,

d = number of operating cycles required for regeneration,

D = number of operating cycles between two cycles where regenerative phases occur.

For exemplary illustration of measurement parameters see below Figure 1 of this Chapter.

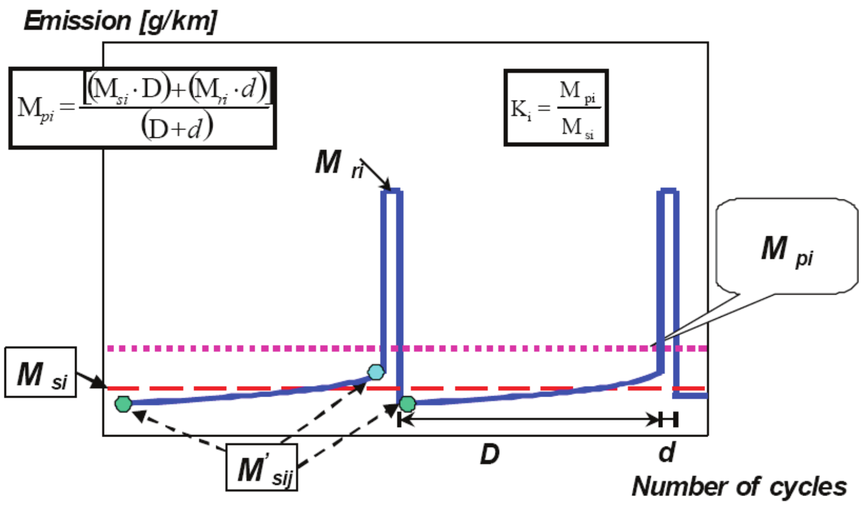


Figure 1

Parameters Measured During Emissions Test During and Between Cycles where Regeneration Occurs (Schematic Example, the Emissions During "D" may Increase or Decrease)

3.3.1. Calculation of the regeneration factor K for each pollutant (i) considered.

The manufacturer may elect to determine for each compound independently either additive offsets or multiplicative factors
$K_i = M_{pi} / M_{si}$ (multiplicative factor)

$K_i = M_{pi} - M_{si}$ (Additive offset)

M_{si}, M_{pi} and K_i results shall be recorded in the test report delivered by the Test Agency.

K_i may be determined following the completion of a single sequence.

3.4. **Calculation of Combined Exhaust Emissions of Multiple Periodic Regenerating Systems.**

$$(1) \quad M_{sik} = \frac{\sum_{j=1}^{n_k} M'_{sik,j}}{n_k} \qquad n_k \geq 2$$

$$(2) \quad M_{rik} = \frac{\sum_{j=1}^{d_k} M'_{rik,j}}{d_j}$$

$$(3) \quad M_{si} = \frac{\sum_{k=1}^{x} M_{sik} \cdot D_k}{\sum_{k=1}^{x} D_k}$$

$$(4) \quad M_{ri} = \frac{\sum_{k=1}^{x} M_{rik} \cdot d_k}{\sum_{k=1}^{x} d_k}$$

$$(5) \quad M_{pi} = \frac{M_{si} \cdot \sum_{k=1}^{x} D_k + M_{ri} \cdot \sum_{k=1}^{x} d_k}{\sum_{k=1}^{x} (D_k + d_k)}$$

$$(6) \quad M_{pi} = \frac{\sum_{k=1}^{x} (M_{sik} \cdot D_k + M_{rik} \cdot d_k)}{\sum_{k=1}^{x} (D_k + d_k)}$$

The manufacturer may elect to determine for each compound independently either additive offsets or multiplicative factors

$$(7) \quad K_i = M_{pi} / M_{si} \quad \text{(multiplicative factor)}$$

$$K_i = M_{pi} - M_{si} \quad \text{(Additive offset)}$$

Where:

M_{si} = mean mass emission of all events k of pollutant (i) in g/km without regeneration,

M_{ri} = mean mass emission of all events k of pollutant (i) in g/km during regeneration,

M_{pi} = mean mass emission of all events k of pollutant (i) in g/km,

M_{sik} = mean mass emission of event k of pollutant (i) in g/km without regeneration,

M_{rik} = mean mass emission of event k of pollutant (i) in g/km during regeneration,

$M'_{sik,j}$ = mass emissions of event k of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) without regeneration measured at point j; $1 \leq j \leq n_k$,

$M'_{rik,j}$ = mass emissions of event k of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) during regeneration (when j > 1, the first Type I test is run cold, and subsequent cycles are hot) measured at operating cycle j; $1 \leq j \leq n_k$,

n_k = number of test points of event k at which emissions measurements (Type I operating cycles or equivalent engine test bench cycles) are made between two cycles where regenerative phases occur, ≥ 2,

d_k = number of operating cycles of event k required for regeneration.

D_k = number of operating cycles of event k between two cycles where regenerative phase occur,

For an illustration of measurement parameters see Figure 2 (below) of this Chapter.

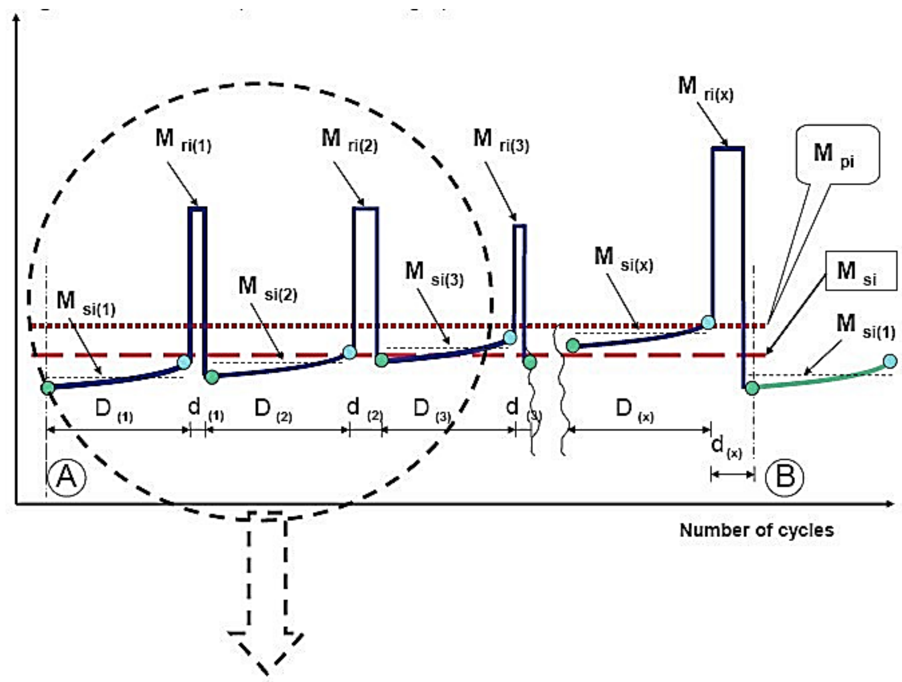


Figure 2

Parameters Measured During Emissions Test During and between Cycles where Regeneration Occurs

(Schematic Example)

For more details of the schematic process see Figure 3 of this Chapter.

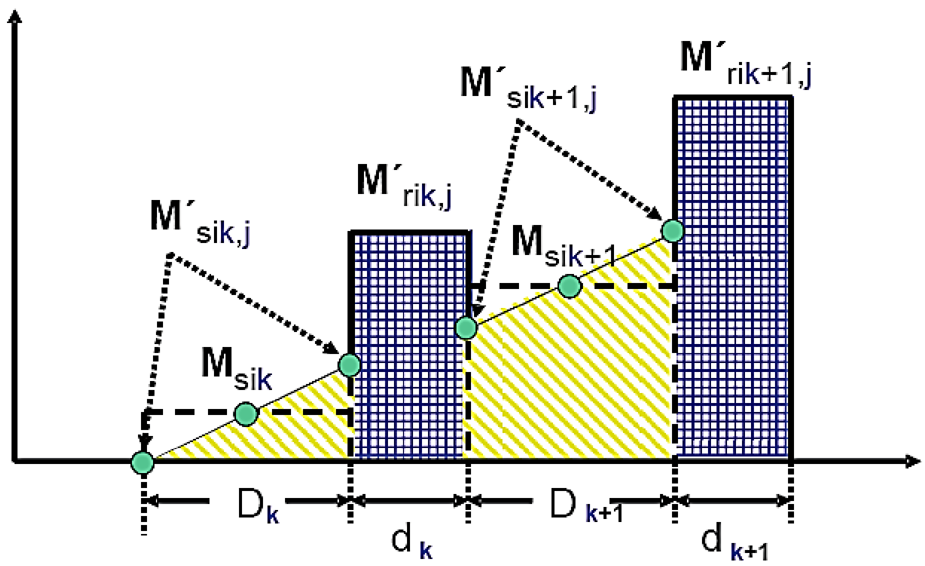


Figure 3

Parameters Measured During Emissions Test During and between Cycles where Regeneration Occurs

(Schematic Example)

(1) For application of a simple and realistic case, the following description gives a detailed explanation of the schematic example shown in Figure 3 above:

Diesel Particulate Filter "DPF": regenerative, equidistant events, similar emissions (±15%) from event to event

$D_k = D_{k+1} = D_1$

$d_k = d_{k+1} = d_1$

$M_{rik} – M_{sik} = M_{rik+1} – M_{sik+1}$

$n_k = n$

(2) "$DeNO_X$": the desulphurization (SO_2 removal) event is initiated before an influence of sulphur on emissions is detectable (±15% of measured emissions) and in this example for exothermic reason together with the last DPF regeneration event performed.

$M'_{sik,j=1}$ = constant
$M_{sik} = M_{sik+1} = M_{si2}$
$M_{rik} = M_{rik+1} = M_{ri2}$
For SO_2 removal event: M_{ri2}, M_{si2}, d_2, D_2, $n_2 = 1$

(3) **COMPLETE SYSTEM (DPF + $DeNO_x$)**

$$M_{si} = \frac{n * M_{si1} * D_1 + M_{si2} * D_2}{n * D_1 + D_2}$$

$$M_{ri} = \frac{n * M_{ri1} * d_1 + M_{ri2} * d_2}{n * d_1 + d_2}$$

$$M_{pi} = \frac{M_{si} + M_{ri}}{n * (D_1 + d_1) + D_2 + d_2} = \frac{n * (M_{si1} * D_1 + M_{ri1} * d_1) + M_{si2} * D_2 + M_{ri2} * d_2}{n * (D_1 + d_1) + D_2 + d_2}$$

The calculation of the factor (K_i) for multiple periodic regenerating systems is only possible after a certain number of regeneration phases for each system. After performing the complete procedure (A to B, see Figure 2), the original starting conditions A should be reached again.

3.4.1. Extension of Approval for a Multiple Periodic Regeneration System

3.4.1.1 If the technical parameter(s) and or the regeneration strategy of a multiple regeneration system for all events within this combined system are changed, the complete procedure including all regenerative devices should be performed by measurements to update the multiple k_i – factor.

3.4.1.2 If a single device of the multiple regeneration system changed only in strategy parameters (i.e. such as "D" and/or "d" for DPF) and the manufacturer could present technical feasible data and information to the Test Agency that:

(a) There is no detectable interaction to the other device(s) of the system; and

(b) The important parameters (i.e. construction, working principle, volume, location etc.) are identical;

The necessary update procedure for k_i could be simplified.

As agreed between the manufacturer and the Test Agency in such a case only a single event of sampling/storage and regeneration should be performed and the test results ("M_si", "M_{ri}") in combination with the changed parameters ("D" and/or "d") could be introduced in the relevant formula(s) to update the multiple k_i - factor in a mathematical way under substitution of the existing basis k_i - factor formula(s)."

CHAPTER 16

REQUIREMENTS FOR VEHICLES THAT USE A REAGENT FOR THE EXHAUST AFTER-TREATMENT SYSTEM

1.0 INTRODUCTION

This Chapter sets out the requirements for vehicles that rely on the use of a reagent for the after-treatment system in order to reduce emissions.

2.0 REAGENT INDICATION

2.1. The vehicle shall include a specific indication/ indicator on the dashboard that informs the driver of low levels of reagent in the reagent storage tank and of when the reagent tank becomes empty.

3.0 DRIVER WARNING SYSTEM

3.1. The vehicle shall include a warning system consisting of visual alarms that informs the driver when the reagent level is low, that the tank soon needs to be refilled, or the reagent is not of a quality specified by the manufacturer. The warning system may also include an audible component to alert the driver.

3.2. The warning system shall escalate in intensity as the reagent approaches empty. It shall culminate in a driver notification that cannot be easily defeated or ignored. It shall not be possible to turn off the system until the reagent has been replenished.

3.3. The visual warning shall display a message indicating a low level of reagent. The warning shall not be the same as the warning used for the purposes of OBD or other engine maintenance. The warning shall be sufficiently clear for the driver to understand that the reagent level is low (e.g. "urea level low", "AdBlue level low", or "reagent low").

3.4. The warning system does not initially need to be continuously activated, however the warning shall escalate so that it becomes continuous as the level of the reagent approaches the point where the driver inducement system in clause 8 of this Chapter. comes into effect. An explicit warning shall be displayed (e.g. "fill up urea"', "fill up AdBlue", or "fill up reagent"). The continuous warning system may be temporarily interrupted by other warning signals providing important safety related messages.

3.5. The warning system shall activate at a distance equivalent to a driving range of at least 2,400 km in advance of the reagent tank becoming empty.

4.0. IDENTIFICATION OF INCORRECT REAGENT

4.1. The vehicle shall include a means of determining that a reagent corresponding to the characteristics declared by the manufacturer and recorded in AIS- 007, as amended from time to time, is present on the vehicle.

4.2. If the reagent in the storage tank does not correspond to the minimum requirements declared by the manufacturer the driver warning system in clause 3 of this Chapter shall be activated and shall display a message indicating an appropriate warning (e.g. "incorrect urea detected", "incorrect AdBlue detected", or "incorrect reagent detected"). If the reagent quality is not rectified within 50 km of the activation of the warning system then the driver inducement requirements of clause 8 of this Chapter shall apply.

5.0. REAGENT CONSUMPTION MONITORING

5.1. The vehicle shall include a means of determining reagent consumption and providing off-board access to consumption information.

5.2. Average reagent consumption and average demanded reagent consumption by the engine system shall be available via the serial port of the standard diagnostic connector. Data shall be available over the previous complete 2,400 km period of vehicle operation.

5.3. In order to monitor reagent consumption, at least the following parameters within the vehicle shall be monitored:

(a) The level of reagent in the on-vehicle storage tank;

(b) The flow of reagent or injection of reagent as close as technically possible to the point of injection into an exhaust after-treatment system.

5.4. A deviation of more than 50% between the average reagent consumption and the average demanded reagent consumption by the engine system over a period of 30 minutes of vehicle operation, shall result in the activation of the driver warning system in clause 3 of this Chapter, which shall display a message indicating an appropriate warning (e.g. "urea dosing malfunction", "AdBlue dosing malfunction", or "reagent dosing malfunction"). If the reagent consumption is not rectified within 50 km of the activation of the warning system then the driver inducement requirements of clause 8 shall apply.

5.5. In the case of interruption in reagent dosing activity the driver warning system as referred to in clause 3 of this Chapter shall be activated, which shall display a message indicating an appropriate warning. This activation shall not be required where the interruption is demanded by the engine ECU because the vehicle operating conditions are such that the vehicle's emission performance does not require reagent dosing, provided that the manufacturer has clearly informed the Test Agency when such operating conditions apply. If the reagent dosing is not rectified within 50 km of the activation of the warning system then the driver inducement requirements of clause 8 of this Chapter shall apply.

6.0. MONITORING NO_X EMISSIONS

6.1. As an alternative to the monitoring requirements in clauses 4 and 5 of this Chapter, manufacturers may use exhaust gas sensors directly to sense excess NO_x levels in the exhaust.

6.2. The manufacturer shall demonstrate that use of these sensors required in clause 6.1 of this Chapter, and any other sensors on the vehicle, results in the activation of the driver warning system as referred to in clause 3., the display of a message indicating an appropriate warning (e.g. "emissions too high – check urea", "emissions too high – check AdBlue", "emissions too high – check reagent"), and the driver inducement system as referred to in clause 8.3., when the situations referred to in clause 4.2, 5.4 or 5.5 of this Chapter occur.

For the purposes of this clause these situations are presumed to occur if the applicable NO_x OBD threshold limit is exceeded as said Gazette Notification.

NO_x emissions during the test to demonstrate the compliance with these requirements shall be no more than 20% higher than the OBD threshold limits.

7.0. STORAGE OF FAILURE INFORMATION

7.1. Where reference is made to this clause, a non-erasable Parameter Identifier (PID) shall be stored identifying the reason for and the distance travelled by the vehicle during the inducement system activation. The vehicle shall retain a record of the PID for at least 800 days or 30,000 km of vehicle operation. The PID shall be made available via the serial port of a standard diagnostic connector upon request of a generic scan tool according to the provision of clause 6.5.3.1 of Appendix 1 of Chapter 14 of this Part. The information stored in the PID shall be linked to the period of cumulated vehicle operation, during which it has occurred, with an accuracy of not less than 300 days or 10,000 km.

7.2. Malfunctions in the reagent dosing system attributed to technical failures (e.g. mechanical or electrical faults) shall also be subject to the OBD requirements in Chapter 14 of this Part.

8.0. DRIVER INDUCEMENT SYSTEM

8.1. The vehicle shall include a driver inducement system to ensure that the vehicle operates with a functioning emissions control system at all times. The inducement system shall be designed so as to ensure that the vehicle cannot operate with an empty reagent tank.

8.2. The inducement system shall activate at the latest when the level of reagent in the tank reaches a level equivalent to the average driving range of the vehicle with a complete tank of fuel. The system shall also activate when the failures in Clauses 4., 5. or 6 of this Chapter have occurred, depending on the NO_x monitoring approach. The detection of an empty reagent tank and the failures mentioned in clauses 4., 5. or 6 of this Chapter shall result in the failure information storage requirements of clause 7. of this Chapter coming into effect.

8.3. The manufacturer shall select which type of inducement system to install. The options for a system are described in clauses 8.3.1, 8.3.2, 8.3.3 and 8.3.4. below.

8.3.1 A "no engine restart after countdown" approach allows a countdown of restarts or distance remaining once the inducement system activates. Engine starts initiated by the vehicle control system, such as start-stop systems, are not included in this countdown. Engine restarts shall be prevented immediately after the reagent tank becomes empty or a distance equivalent to a complete tank of fuel has been exceeded since the activation of the inducement system, whichever occurs earlier.

8.3.2 A "no start after refueling" system results in a vehicle being unable to start after re-fueling if the inducement system has activated.

8.3.3 A "fuel-lockout" approach prevents the vehicle from being refuelled by locking the fuel filler system after the inducement system activates. The lockout system shall be robust to prevent it being tampered with.

8.3.4. A "performance restriction" approach restricts the speed of the vehicle after the inducement system activates. The level of speed limitation shall be noticeable to the driver and significantly reduce the maximum speed of the vehicle. Such limitation shall enter into operation gradually or after an engine start. Shortly before engine restarts are prevented, the speed of the vehicle shall not exceed 50 km/h. Engine restarts shall be prevented immediately after the reagent tank becomes empty or a distance equivalent to a complete tank of fuel has been exceeded since the activation of inducement system, whichever occurs earlier.

8.4. Once the inducement system has fully activated and disabled the vehicle, the inducement system shall only be deactivated if the quantity of reagent added to the vehicle is equivalent to 2,400 km average driving range, or the failures specified in clauses 4., 5., or 6. of this Chapter have been rectified. After a repair has been carried out to correct a fault where the OBD system has been triggered under clause 7.2 of this Chapter, the inducement system may be reinitialized via the OBD serial port (e.g. by a generic scan tool) to enable the vehicle to be restarted for self-diagnosis purposes. The vehicle shall operate for a maximum of 50 km to enable the success of the repair to be validated. The inducement system shall be fully reactivated if the fault persists after this validation.

8.5. The driver warning system referred to in clause 3 of this Chapter shall display a message indicating clearly:

(a) The number of remaining restarts and/or the remaining distance; and

(b) The conditions under which the vehicle can be restarted.

8.6. The driver inducement system shall be deactivated when the conditions for its activation have ceased to exist. The driver inducement system shall not be automatically deactivated without the reason for its activation having been remedied.

8.7. Detailed written information fully describing the functional operation characteristics of the driver inducement system shall be provided to the Test Agency at the time of approval.

8.8 As part of the application for type approval under this Part, the manufacturer shall demonstrate the operation of the driver warning and inducement systems

9.0. INFORMATION REQUIREMENTS

9.1. The manufacturer shall provide all owners of new vehicles written information about the emission control system. This information shall state that if the vehicle emission control system is not functioning correctly, the driver shall be informed of a problem by the driver warning system and that the driver inducement system shall consequentially result in the vehicle being unable to start.

9.2. The instructions shall indicate requirements for the proper use and maintenance of vehicles, including the proper use of consumable reagents.

9.3. The instructions shall specify if consumable reagents have to be refilled by the vehicle operator between normal maintenance intervals. They shall indicate how the driver should refill the reagent tank. The information shall also indicate a likely rate of reagent consumption for that type of vehicle and how often it should be replenished.

9.4. The instructions shall specify that use of, and refilling of, a required reagent of the correct specifications is mandatory for the vehicle to comply with the certificate of conformity issued for that vehicle type.

9.5. The instructions shall state that it may be a criminal offence to use a vehicle that does not consume any reagent if it is required for the reduction of emissions.

9.6. The instructions shall explain how the warning system and driver inducement systems work. In addition, the consequences of ignoring the warning system and not replenishing the reagent shall be explained.

10.0 OPERATING CONDITIONS OF THE AFTER-TREATMENT SYSTEM

Manufacturers shall ensure that the emission control system retains its emission control function during all ambient conditions above zero deg. The manufacturer may use a heated or a non-heated reagent tank and dosing system. OBD system shall monitor urea dozing if ambient temperature > 0 Deg. C.

CHAPTER 17

EMISSIONS TEST PROCEDURE FOR HYBRID ELECTRIC VEHICLES (HEV)

1.0 INTRODUCTION

1.1. This Chapter defines the specific provisions regarding type-approval of a Hybrid Electric Vehicle (HEV) as defined in clause 2.21.2. of Chapter 1 of this Part.

1.2. As a general principle, for the tests of Type I, II, III, IV, V and OBD, hybrid electric vehicles shall be tested according to Chapter 3, 9, 10, 11, 12 and 14 of this part respectively, unless modified by this Chapter.

1.3. For the Type I test only, OVC vehicles (as categorized in clause 2 of this Chapter) shall be tested according to condition A and to condition B. The test results under both conditions A and B and the weighted values shall be reported in the communication form.

1.4. The emissions test results shall comply with the limits under all specified test conditions of this Part.

2.0. CATEGORIES OF HYBRID ELECTRIC VEHICLES

Vehicle charging	Off-vehicle charging[1] (OVC)		Not off-vehicle charging[2] (NOVC)	
Operating mode switch	Without	With	Without	With

1. Also known as "externally chargeable"

2. Also known as "not externally chargeable"

3.0. TYPE I TEST METHODS

3.1. Externally Chargeable (OVC HEV) without an Operating Mode Switch

3.1.1. Two tests shall be performed under the following conditions:

Condition A: Test shall be carried out with a fully charged electrical energy/power storage device.

Condition B: Test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

The profile of the state of charge (SOC) of the electrical energy/power storage device during different stages of the Type I test is given in this Chapter.

3.1.2. Condition A

3.1.2.1. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up;

Or, if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between Test Agency and manufacturer);

(c) Or with manufacturer's recommendation.
The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.1.2.2. Conditioning of Vehicle

3.1.2.2.1. For compression-ignition engine vehicles the Part Two cycle of Type I test shall be used. Three consecutive cycles shall be driven according to clause 3.1.2.5.3 of this Chapter.

3.1.2.2.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to clause 3.1.2.5.3. of this Chapter.

3.1.2.3. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303K (20°C and 30°C). This conditioning shall be carried out for at least 6 hours and continue until the engine oil temperature and coolant, if any, are within ±2 K of the temperature of the room, and the electrical energy/power storage device is fully charged as a result of the charging prescribed in clause 3.1.2.4. of this Chapter.

3.1.2.4 During soak, the electrical energy/power storage device shall be charged:

(a) With the on board charger if fitted; or

(b) With an external charger recommended by the manufacturer, using the normal overnight charging procedure.

(c) This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalization charges or the servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred.

3.1.2.5. Test procedure

3.1.2.5.1 The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.1.2.5.2 The test procedures defined in either clause 3.1.2.5.2.1 or 3.1.2.5.2.2 of this Chapter may be used.

3.1.2.5.2.1 Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.1.2.5.2.2 Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and continue over a number of repeat test cycles. It shall end on conclusion of the final idling period in the first extra-urban (Part Two) cycle during which the battery reached the minimum state of charge according to the criterion defined below (end of sampling (ES)).

The electricity balance Q [Ah] is measured over each combined cycle using the procedure specified in Appendix 1 of Chapter 19A of this Part and used to determine when the battery minimum state of charge has been reached

The battery minimum state of charge is considered to have been reached in combined cycle N if the electricity balance measured during combined cycle N+1 is not more than a 3% discharge, expressed as a percentage of the nominal capacity of the battery (in Ah) in its maximum state of charge, as declared by the manufacturer. At the manufacturer's request additional test cycles may be run and their results included in the calculations in clauses 3.1.2.5.5 and 3.1.4.2 of this Chapter provided that the electricity balance for each additional test cycle shows less discharge of the battery than over the previous cycle.

Between each of the cycles a hot soak period of up to 10 minutes is allowed. The power train shall be switched off during this period.

3.1.2.5.3. The vehicle shall be driven according to provisions in Chapter 3 of this Part or in case of special gear shifting strategy, according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers' information). For these vehicles the gear shifting points prescribed in Chapter 3 of this Part are not applied. For the pattern of the operating curve the description according to clause 5.2 of Chapter 3 to this Part shall apply.

3.1.2.5.4. The exhaust gases shall be analyzed according to provisions in Chapter 3 of this Part.

3.1.2.5.5. The test results shall be compared to the limits prescribed in said Gazette Notification and the average emission of each pollutant in grams per kilometer for Condition A shall be calculated (M_{1i}).

In the case of testing according to clause 3.1.2.5.2.1.,of this Chapter, (M_{1i}) is simply the result of the single combined cycle run.

In the case of testing according to clause 3.1.2.5.2.2., of this Chapter the test result of each combined cycle run (M_{1ia}), multiplied by the appropriate deterioration and K_i factors, shall be less than the limits prescribed in clause 5.3.1.4. of Chapter 1 to this Part. For the purposes of the calculation in clause 3.1.4 of this Chapter M_{1i} shall be defined as:

$$M_{1i} = \frac{1}{N}\sum_{a=1}^{N} M_{1ia}$$

Where:
i: pollutant
a: cycle

3.1.3. Condition B

3.1.3.1. Conditioning of Vehicle

3.1.3.1.1. For compression-ignition engined vehicles the Part Two cycle of Type I test shall be used. Three consecutive cycles shall be driven according to clause 3.1.3.4.3 of this Chapter.

3.1.3.1.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to clause 3.1.3.4.3. of this Chapter.

3.1.3.2. The electrical energy/power storage device of the vehicle shall be discharged while driving (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up;

(b) Or if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between Test Agency and manufacturer);

(c) Or with manufacturers' recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.1.3.3 After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20°C and 30°C). This conditioning shall be carried out for at least 6 hours and continue until the engine oil temperature and coolant, if any, are within ±2 K of the temperature of the room.

3.1.3.4 Test Procedure

3.1.3.4.1 The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.1.3.4.2 Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.1.3.4.3 The vehicle shall be driven according to Chapter 3 of this Part or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Chapter 3 of this Part are not applied. For the pattern of the operating curve the description according to clause 5.2 of Chapter 3 of this Part shall apply.

3.1.3.4.4 The exhaust gases shall be analyzed according to Chapter 3 of this Part.

3.1.3.5 The test results shall be compared to the limits prescribed in clause 5.3.1.4. of Chapter 1 of this Part and the average emission of each pollutant for Condition B shall be calculated (M_{2i}). The test results M_2i, multiplied by the appropriate deterioration and K_i factors, shall be less than the limits prescribed in clause 5.3.1.4 of Chapter 1 of this Part.

3.1.4 Test Results

3.1.4.1 In the case of testing according to clause 3.1.2.5.2.1. of this Chapter

For communication, the weighted values shall be calculated as below:

$M_i = (D_e \bullet M_{1i} + D_{av} \bullet . M_{2i})/(D_e + D_{av})$

Where:

M_i = mass emission of the pollutant i in grams per kilometer

M_{1i} = average mass emission of the pollutant i in grams per kilometre with a fully charged electrical energy/power storage device calculated in clause 3.1.2.5.5.of this chapter,

M_{2i} = average mass emission of the pollutant i in grams per kilometer with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) calculated in clause 3.1.3.5. of this Chapter.

D_e = vehicle electric range, according to the procedure described in Appendix 2 of Chapter 19 A of this Part, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric mode,

Dav = 25 km (average distance between two battery recharges).

3.1.4.2 In the case of testing according to clause 3.1.2.5.2.2. of this Chapter.

For communication, the weighted values shall be calculated as below:

$M_i = (D_{ovc} \cdot M_{1i} + D_{av} \cdot M_{2i})/(D_{ovc} + D_{av})$

Where:

M_i = mass emission of the pollutant i in grams per kilometer,

M_{1i} = average mass emission of the pollutant i in grams per kilometer with a fully charged electrical energy/power storage device calculated in clause 3.1.2.5.5. of this Chapter.

M_{2i} = average mass emission of the pollutant i in grams per kilometer with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) calculated in clause 3.1.3.5. of this Chapter.

D_{ovc} = OVC range according to the procedure described in Appendix 2 of Chapter 19 A of this Part

D_{av} = 25 km (average distance between two battery recharges).

3.2. **Externally Chargeable (OVC HEV) with an Operating Mode Switch**

3.2.1. Two tests shall be performed under the following conditions:

3.2.1.1. Condition A: Test shall be carried out with a fully charged electrical energy/power storage device.

3.2.1.2. Condition B: Test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

3.2.1.3. The operating mode switch shall be positioned according the Table 1 below:

Table 1

Hybrid-modes / Battery state of charge	- Pure electric - Hybrid Switch in position	- Pure fuel consuming - Hybrid Switch in position	- Pure electric - Pure fuel consuming - Hybrid Switch in position	- Hybrid mode n[1] … - Hybrid mode m[1] Switch in position
Condition A Fully charged	Hybrid	Hybrid	Hybrid	Most electric hybrid mode[2]
Condition B Min. state of charge	Hybrid	Fuel consuming	Fuel consuming	Most fuel consuming mode[3]

Notes:

(1) For instance: sport, economic, urban, extra-urban position.

(2) Most electric hybrid mode:

The hybrid mode which can be proven to have the highest electricity consumption of all selectable hybrid modes when tested in accordance with condition A of clause 3.2of this Chapter, to be established based on information provided by the manufacturer and in agreement with the Test Agency.

(3) Most fuel consuming mode:

The hybrid mode which can be proven to have the highest fuel consumption of all selectable hybrid modes when tested in accordance with condition B of clause 3.2 of this Chapter, to be established based on information provided by the manufacturer and in agreement with the Test Agency.

3.2.2. Condition A

3.2.2.1. If the pure electric range of the vehicle is higher than one complete cycle, on the request of the manufacturer, the Type I test may be carried out in pure electric mode. In this case, engine preconditioning prescribed in clause 3.2.2.3.1. or 3.2.2.3.2. of this Chapter can be omitted.

3.2.2.2. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70% ±5% of the maximum 30 minutes speed of the vehicle (Determined according to Chapter 19A of this Part).

Stopping the discharge occurs:

(a) When the vehicle is not able to run at 65% of the maximum 30 minutes speed; or

(b) When an indication to stop the vehicle is given to the driver by the standard on-board instrumentation; or

(c) After covering the distance of 100 km.

If the vehicle is not equipped with a pure electric mode, the electrical energy/power storage device discharge shall be achieved by driving the vehicle (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up; or

(b) If a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between Test Agency and manufacturer); or

(c) With manufacturers' recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.2.2.3. **Conditioning of vehicle**

3.2.2.3.1. For compression-ignition engined vehicles the Part Two cycle of Type I test described in Chapter 3 to this Part shall be used. Three consecutive cycles shall be driven according to clause 3.2.2.6.3. of this Chapter.

3.2.2.3.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to clause 3.2.2.6.3 of this Chapter.

3.2.2.4. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20°C and 30 °C). This conditioning shall be carried out for at least 6 hours and continue until the engine oil temperature and coolant, if any, are within ±2 K of the temperature of the room, and the electrical energy/power storage device is fully charged as a result of the charging prescribed in clause 3.2.2.5. of this Chapter

3.2.2.5. During soak, the electrical energy/power storage device shall be charged:

(a) With the on board charger if fitted; or

(b) With an external charger recommended by the manufacturer, using the normal overnight charging procedure.

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalization charges or the servicing charges.

The manufacturer shall declare that during the test, a special charge procedure has not occurred.

3.2.2.6. Test Procedure

3.2.2.6.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.2.2.6.2. The test procedures defined in either clause 3.2.2.6.2.1. or 3.2.2.6.2.2. of this Chapter may be used in line with procedure chosen in clause 4. Of Chapter 19A of this Part.

3.2.2.6.2.1 Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.2.2.6.2.2 Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and continue over a number of repeat test cycles. It shall end on conclusion of the final idling period in the first extra-urban (Part Two) cycle during which the battery has reached the minimum state of charge according to the criterion defined below (end of sampling (ES)).

The electricity balance Q [Ah] is measured over each combined cycle, using the procedure specified in Appendix 1 of Chapter 19 A to this Part, and used to determine when the battery minimum state of charge has been reached.

The battery minimum state of charge is considered to have been reached in combined cycle N if the electricity balance measured during combined cycle N+1 is not more than a 3% discharge, expressed as a percentage of the nominal capacity of the battery (in Ah) in its maximum state of charge, as declared by the manufacturer. At the manufacturer's request additional test cycles may be run and their results included in the calculations in clauses 3.2.2.7. and 3.2.4.3. of this Chapter provided that the electricity balance for each additional test cycle shows less discharge of the battery than over the previous cycle.

Between each of the cycles a hot soak period of up to 10 minutes is allowed. The power train shall be switched off during this period.

3.2.2.6.3. The vehicle shall be driven according to Type I test described in Chapter 3 of this Part or in case of special gear shifting strategy, according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers' information). For these vehicles the gear shifting points prescribed in Chapter 3 of this Part are not applied. For the pattern of the operating curve the description according to clause 5.2. of Chapter 3 of this Part shall apply.

3.2.2.6.4. The exhaust gases shall be analyzed according to Chapter 3 of this Part.

3.2.2.7. The test results shall be compared to the limits prescribed in clause 5.3.1.4. of Chapter 1 to this Part and the average emission of each pollutant in grams per kilometer for Condition A shall be calculated (M_{1i}).

In the case of testing according to clause 3.2.2.6.2.1., of this Chapter (M_{1i}) is simply the result of the single combined cycle run.

In the case of testing according to clause 3.2.2.6.2.2., of this Chapter the test result of each combined cycle run M_{1ia}, multiplied by the appropriate deterioration and K_i factors, shall be less than the limits prescribed in clause 5.3.1.4. of Chapter 1 of this Part. For the purposes of the calculation in clause 3.2.4., of this Chapter M_{1i} shall be defined as:

$$M_{1i} = \frac{1}{N}\sum_{a=1}^{N} M_{1ia}$$

Where:

i = pollutant

a = cycle

3.2.3 Condition B

3.2.3.1 Conditioning of Vehicle

3.2.3.1.1 For compression-ignition engined vehicles the Part Two cycle described in Type I test of Chapter 3 of this Part shall be used. Three consecutive cycles shall be driven according to clause 3.2.3.4.3. of this Chapter.

3.2.3.1.2 Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to clause 3.2.3.4.3. of this Chapter.

3.2.3.2 The electrical energy/power storage device of the vehicle shall be discharged according to clause 3.2.2.2. of this Chapter

3.2.3.3 After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20°C and 30°C). This conditioning shall be carried out for at least 6 hours and continue until the engine oil temperature and coolant, if any, are within ±2 K of the temperature of the room.

3.2.3.4 Test Procedure

3.2.3.4.1 The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.2.3.4.2 Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.2.3.4.3 The vehicle shall be driven according to Chapter 3 of this Part, or in case of special gear shifting strategy, according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers' information). For these vehicles the gear shifting points prescribed in Chapter 3 to this Part are not applied. For the pattern of the operating curve the description according to clause 5.2. of Chapter 3 of this Part shall apply.

3.2.3.4.4 The exhaust gases shall be analyzed according to Chapter 3 of this Part.

3.2.3.5 The test results shall be compared to the limits prescribed in clause 5.3.1.4. of Chapter 1 of this Part and the average emission of each pollutant for condition B shall be calculated (M_{2i}). The test results M_{2i}, multiplied by the appropriate deterioration and K_i factors, shall be less than the limits prescribed in Paragraph 5.3.1.4. of Chapter 1 of this Part.

3.2.4 Test Results

In the case of testing according to clause 3.2.2.6.2.1. of this Chapter

For communication, the weighted values shall be calculated as below:

$$M_i = (D_e \bullet M_{1i} + D_{av} \bullet M_{2i}) / (D_e + D_{av})$$

Where:

M_i = mass emission of the pollutant i in grams per kilometer,

M_{1i} = average mass emission of the pollutant i in grams per kilometer with a fully charged electrical energy/power storage device calculated in clause 3.2.2.7, of this Chapter

M_{2i} = average mass emission of the pollutant i in grams per kilometer with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) calculated in clause 3.2.3.5, of this chapter

D_e = vehicle electric range with the switch in pure electric position, according to the procedure described in Appendix 2 of Chapter 19A of this Part. If there is not a pure electric position, the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric mode.

D_{av} = 25 km (average distance between two battery recharge).

In the case of testing according to clause 3.2.2.6.2.2. of this Chapter

For communication, the weighted values shall be calculated as below:

$$M_i = (D_{ovc} \cdot M_{1i} + D_{av} \cdot M_{2i})/(D_{ovc} + D_{av})$$

Where :

M_i = mass emission of the pollutant i in grams per kilometer,

M_{1i} = average mass emission of the pollutant i in grams per kilometer with a fully charged electrical energy/power storage device calculated in clause 3.2.2.7. of this Chapter

M_{2i} = average mass emission of the pollutant i in grams per kilometer with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) calculated in clause 3.2.3.5. of this Chapter

D_{ovc} = OVC range according to the procedure described in Appendix 2 of Chapter 19A to this Part

D_{av} = 25 km (average distance between two battery recharges).

3.3. **Not externally Chargeable (Not-OVC HEV) without an Operating Mode Switch**

3.3.1. These vehicles shall be tested according to Chapter 3 of this Part.

3.3.2. For preconditioning, at least two consecutive complete driving cycles (one Part One and one Part Two) are carried out without soak.

3.3.3. The vehicle shall be driven according to Chapter 3 of this Part, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Chapter 3 of this Part are not applied. For the pattern of the operating curve the description according to clause 5.2. of Chapter 3 of this Part shall apply.

3.4. **Not Externally chargeable (not-OVC HEV) With an Operating Mode Switch**

3.4.1. These vehicles are preconditioned and tested in hybrid mode as per Chapter 3 of this Part. If several hybrid modes are available, the test shall be carried out in the mode that is automatically set after turn on of the ignition key (normal mode). On the basis of information provided by the manufacturer, the Test Agency will make sure that the limit values are met in all hybrid modes.

3.4.2. For preconditioning, at least two consecutive complete driving cycles (one Part One and one Part Two) shall be carried out without soak.

3.4.3. The vehicle shall be driven according to Chapter 3 of this Part, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Chapter 3 of this Part are not applied. For the pattern of the operating curve the description according to clause 5.2. of Chapter 3 of this Part shall apply.

4.0 TYPE II TEST METHODS

4.1. The vehicles shall be tested according to Chapter 9 of this Part with the fuel consuming engine running. The manufacturer shall provide a "service mode" that makes execution of this test possible.

5.0 TYPE III TEST METHODS

5.1. The vehicles shall be tested according to Chapter 10 of this Part with the fuel consuming engine running. The manufacturer shall provide a "service mode" that makes execution of this test possible.

5.2. The tests shall be carried out only for conditions 1 and 2 of the clause 3.2. of Chapter 10 of this Part. If for any reasons it is not possible to test on condition 2, alternatively another steady speed condition (with fuel consuming engine running under load) should be carried out.

6.0 TYPE IV TEST METHODS

6.1. The vehicles shall be tested according to Chapter 11 of this Part.

6.2. Before starting the test procedure (clause 5.1. of Chapter 11 of this Part), the vehicles shall be preconditioned as follows:

6.2.1. For OVC vehicles:

6.2.1.1. OVC vehicles without an operating mode switch: the procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up; or

(b) If a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between Test Agency and manufacturer); or

(c) With manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

6.2.1.2. OVC vehicles with an operating mode switch: the procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70% ±5% from the maximum 30 minutes speed of the vehicle.

Stopping the discharge occurs:

(a) When the vehicle is not able to run at 65% of the maximum 30 minutes speed; or

(b) When an indication to stop the vehicle is given to the driver by the standard on-board instrumentation; or

(c) After covering the distance of 100 km.

If the vehicle is not equipped with a pure electric mode, the electrical energy/power storage device discharge shall be conducted with the vehicle driving (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up; or

(b) If a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between Test agency and manufacturer); or

(c) With manufacturer's recommendation.

The engine shall be stopped within 10 seconds of it being automatically started.

6.2.2. **For NOVC vehicles:**

6.2.2.1. NOVC vehicles without an operating mode switch: the procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak.

6.2.2.2. NOVC vehicles with an operating mode switch: the procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak, performed with the vehicle running in hybrid mode. If several hybrid modes are available, the test shall be carried out in the mode which is automatically set after turn on of the ignition key (normal mode).

6.3. The preconditioning drive and the dynamometer test shall be carried out according to clauses 5.2. and 5.4. of Chapter 11 of this Part.

6.3.1. For OVC vehicles: under the same conditions as specified by condition B of the Type I test (clauses 3.1.3. and 3.2.3. of this Chapter).

6.3.2. For NOVC vehicles: under the same conditions as in the Type I test.

7.0 TYPE V TEST METHODS

7.1. The vehicles shall be tested according to Chapter 12 of this Part

7.2. For OVC vehicles:

It is allowed to charge the electrical energy/power storage device twice a day during mileage accumulation.

For OVC vehicles with an operating mode switch, mileage accumulation should be driven in the mode which is automatically set after turn on of the ignition key (normal mode).

During the mileage accumulation a change into another hybrid mode is allowed if necessary in order to continue the mileage accumulation after agreement of the Test Agency.

The measurements of emissions of pollutants shall be carried out under the same conditions as specified by condition B of the Type I test (clauses 3.1.3. and 3.2.3. of this Chapter).

7.3. For NOVC vehicles:

For NOVC vehicles with an operating mode switch, mileage accumulation shall be driven in the mode which is automatically set after turn on of the ignition key (normal mode).

The measurements of emissions of pollutants shall be carried out in the same conditions as in the Type I test.

8.0 ON BOARD DIAGNOSTICS (OBD) TEST METHODS

8.1. The vehicles shall be tested according to Chapter 14 to this Part.

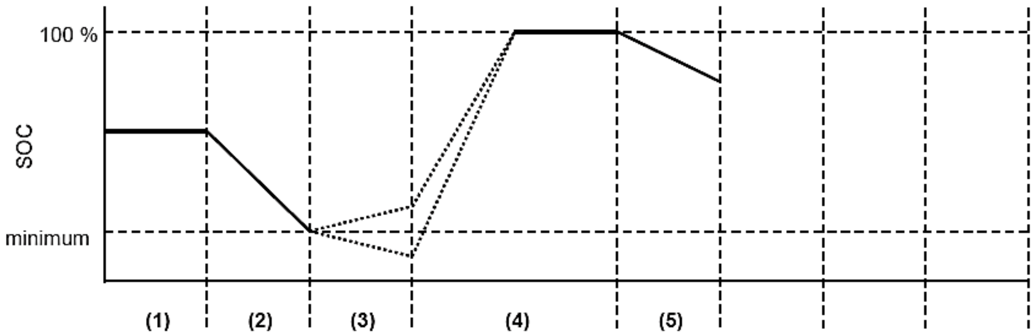
8.2. For OVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as specified for condition B of the Type I test (clauses 3.1.3. and 3.2.3. of this Chapter).

8.3. For NOVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as in the Type I test.

CHAPTER 17 - APPENDIX 1

ELECTRICAL ENERGY/POWER STORAGE DEVICE STATE OF CHARGE (SOC) PROFILE FOR OVC HEV TYPE I TEST

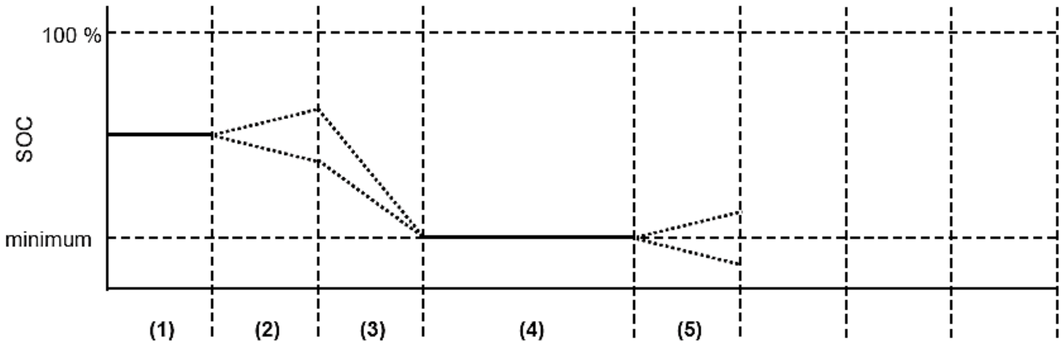
Condition A of the Type I test



Condition A:

(1) Initial electrical energy/power storage device state of charge
(2) Discharge according to clause 3.1.2.1. or 3.2.2.2. of this Chapter
(3) Vehicle conditioning according to clause 3.1.2.2. or 3.2.2.3 of this Chapter
(4) Charge during soak according to clauses 3.1.2.3. and 3.1.2.4., of this Chapter or clauses 3.2.2.4 and 3.2.2.5 of this Chapter
(5) Test according to clause 3.1.2.5. or 3.2.2.6 of this Chapter

Condition B of the Type I test



Condition B:

(1) Initial state of charge
(2) Vehicle conditioning according to clause 3.1.3.1 or 3.2.3.1 of this Chapter
(3) Discharge according to clause 3.1.3.2. or 3.2.3.2. of this Chapter
(4) Soak according to clause 3.1.3.3. or 3.2.3.3. of this Chapter
(5) Test according to clause 3.1.3.4. or 3.2.3.4 of this Chapter

CHAPTER 18 - APPENDIX 1

IN-SERVICE CONFORMITY CHECK

1.0 INTRODUCTION

This Appendix sets out the criteria referred to clause 9.3 and 9.4. of Chapter 1 of this Part regarding the selection of vehicles for testing and the procedures for the in-service conformity control.

2.0 SELECTION CRITERIA

The criteria for acceptance of a selected vehicle are defined for tailpipe emissions in clauses 2.1 to 2.8 of this Appendix and for $IUPR_M$ in clauses 2.1 to 2.5 of this Appendix. Information is collected by vehicle examination and an interview with the owner/driver.

2.1. The vehicle shall belong to a vehicle type that is type approved under this Part and covered by a certificate of conformity.

2.2. The vehicle shall have been in service for at least 15000 km or 6 months, whichever is the later, and for no more than 100000 km or 5 years, whichever is sooner.

2.2.1. For checking $IUPR_M$, the test sample shall include only vehicles that:

(a) Have collected sufficient vehicle operation data for the monitor to be tested.

For monitors required to meet the in-use monitor performance ratio and to track and report ratio data pursuant to clause 7.6.1 of Appendix 1 to Chapter 14 to this Part sufficient vehicle operation data shall mean the denominator meets the criteria set forth below. The denominator, as defined in clause 7.3 and 7.5 of Appendix 1 to Chapter 14 to this Part for the monitor to be tested shall have a value equal to or greater than one of the following values:

(i) 75 for evaporative system monitors, secondary air system monitors, and monitors utilizing a denominator incremented in accordance with clause 7.3.2 sub-clauses (a), (b) or (c) of Appendix 1 of Chapter 14 of this Part (e.g. cold start monitors, air conditioning system monitors, etc.); or

(ii) 25 for particulate filter monitors and oxidation catalyst monitors utilizing a denominator incremented in accordance with clause 7.3.2 sub-clauses (d) of Appendix 1 of Chapter 14 of this Part; or

(iii) 150 for catalyst, oxygen sensor, EGR, VVT, and all other component monitors;

(b) Have not been tampered with or equipped with add-on or modified parts that would cause the OBD system not to comply with the requirements of Chapter 14 of this Part.

2.3. There shall be a maintenance record to show that the vehicle has been properly maintained, e.g. has been serviced in accordance with the manufacturer's recommendations.

2.4. The vehicle shall exhibit no indications of abuse (e.g. racing, overloading, misfuelling, or other misuse), or other factors (e.g. tampering) that could affect emission performance. The fault code and mileage information stored in the computer is taken into account. A vehicle shall not be selected for testing if the information stored in the computer shows that the vehicle has operated after a fault code was stored and a relatively prompt repair was not carried out.

2.5. There shall have been no unauthorized major repair to the engine or major repair of the vehicle.

2.6. The lead content and sulphur content of a fuel sample from the vehicle tank shall meet applicable standards and there shall be no evidence of misfuelling. Checks may be done in the exhaust, etc.

2.7. There shall be no indication of any problem that might affect the safety of laboratory personnel.

2.8. All anti-pollution system components on the vehicle shall be in conformity with the applicable type approval.

3.0 DIAGNOSIS AND MAINTENANCE

Diagnosis and any normal maintenance necessary shall be performed on vehicles accepted for testing, prior to measuring exhaust emissions, in accordance with the procedure laid down in clauses 3.1 to 3.8 of this Appendix.

3.1. The following checks shall be carried out: checks on air filter, all drive belts, all fluid levels, radiator cap, all vacuum hoses and electrical wiring related to the anti-pollution system for integrity; checks on ignition, fuel metering and anti-pollution device components for maladjustments and/or tampering. All discrepancies shall be recorded.

3.2. The OBD system shall be checked for proper functioning. Any malfunction indications in the OBD memory shall be recorded and the requisite repairs shall be carried out. If the OBD malfunction indicator registers a malfunction during a preconditioning cycle, the fault may be identified and repaired. The test may be re-run and the results of that repaired vehicle used.

3.3. The ignition system shall be checked and defective components replaced, for example spark plugs, cables, etc.

3.4. The compression shall be checked. If the result is unsatisfactory the vehicle is rejected.

3.5. The engine parameters shall be checked to the manufacturer's specifications and adjusted if necessary.

3.6. If the vehicle is within 800 km of a scheduled maintenance service, that service shall be performed according to the manufacturer's instructions. Regardless of odometer reading, the oil and air filter may be changed at the request of the manufacturer.

3.7. Upon acceptance of the vehicle, the fuel shall be replaced with appropriate emission test reference fuel, unless the manufacturer accepts the use of market fuel.

3.8. In the case of vehicles equipped with periodically regenerating systems as defining in clause 2.20 of Chapter 1 of this Part, it shall be established that the vehicle is not approaching a regeneration period. (The manufacturer shall be given the opportunity to confirm this).

3.8.1. If this is the case, the vehicle shall be driven until the end of the regeneration. If regeneration occurs during emissions measurement, then a further test shall be carried out to ensure that regeneration has been completed. A complete new test shall then be performed, and the first and second test results not taken into account.

3.8.2. As an alternative to clause 3.8.1 of this Appendix, if the vehicle is approaching a regeneration the manufacturer may request that a specific conditioning cycle is used to ensure that regeneration (e.g. this may involve high speed, high load driving).

The manufacturer may request that testing may be carried out immediately after regeneration or after the conditioning cycle specified by the manufacturer and normal test preconditioning.

4.0 IN-SERVICE TESTING

4.1. When a check on vehicles is deemed necessary, emission tests in accordance with Chapter 3 of this Part are performed on pre-conditioned vehicles selected in accordance with the requirements of clauses 2 and 3 of this Appendix. Pre-conditioning cycles additional to those specified in clause 6.10 of Chapter 3 of this Part will only be allowed if they are representative of normal driving.

4.2. Vehicles equipped with an OBD system may be checked for proper in-service functionality of the malfunction indication, etc., in relation to levels of emissions (e.g. the malfunction indication limits defined in Gazette Notification for the type-approved specifications.

4.3. The OBD system may be checked, for example, for levels of emissions above the applicable limit values with no malfunction indication, systematic erroneous activation of the malfunction indication and identified faulty or deteriorated components in the OBD system.

4.4. If a component or system operates in a manner not covered by the particulars in the type approval certificate and/or information package for such vehicle types with no malfunction indication by the OBD, the component or system shall not be replaced prior to emission testing, unless it is determined that the component or system has been tampered with or abused in such a manner that the OBD does not detect the resulting malfunction.

5.0 EVALUATION OF EMISSION TEST RESULTS

5.1. The test results are submitted to the evaluation procedure as indicated in this Appendix 2 of this Chapter.

5.2. Test results shall not be multiplied by deterioration factors.

5.3. In the case of periodically regenerating systems as defined in clause 2.20 of Chapter 1 of this Part, the results shall be multiplied by the factors K_i obtained at the time when type approval was granted.

6.0. PLAN OF REMEDIAL MEASURES

6.1. The Test Agency shall request the manufacturer to submit a plan of remedial measures to remedy the non-compliance when:

6.1.1. For tailpipe emissions more than one vehicle is found to be an outlying emitter that meets either of the following conditions:

(a) The conditions of clause 3.2.2 of Appendix 2 of this Chapter and where both the Testing Agency and the manufacturer agree that the excess emission is due to the same cause; or

(b) The conditions of clause 3.2.3 of Appendix 2 of this Chapter where the Test Agency has determined that the excess emission is due to the same cause.

The Test Agency shall request the manufacturer to submit a plan of remedial measures to remedy the non-compliance;

6.1.2. For $IUPR_M$ of a particular monitor M the following statistical conditions are met in a test sample, the size of which is determined according to clause 9.3.5 of Chapter 1 of this Part:

(a) For vehicles certified to a ratio of 0.1 in accordance with clause 7.1.4 of Appendix 1 of Chapter 14 of this Part, the data collected from the vehicles indicate for at least one monitor M in the test sample either that the test sample average in-use-performance ratio is less than 0.1 or that 66% or more of the vehicles in the test sample have an in-use monitor performance ratio of less than 0.1.

6.2. The plan of remedial measures shall be filed with the Test Agency not later than 60 working days from the date of the notification referred to in clause 6.1 above. Test Agency shall within 30 working days declare its approval or disapproval of the plan of remedial measures. However, where the manufacturer can demonstrate, to the satisfaction of the Test Agency, that further time is required to investigate the non-compliance in order to submit a plan of remedial measures, an extension is granted.

6.3. The remedial measures shall apply to all vehicles likely to be affected by the same defect.

The need to amend the type approval documents shall be assessed.

6.4. The manufacturer shall provide a copy of all communications related to the plan of remedial measures, and shall also maintain a record of the recall campaign, and supply regular status reports to the Test Agency and Nodal Agency.

6.5. The plan of remedial measures shall include the requirements specified in clauses 6.5.1 to 6.5.11 of this Appendix. The manufacturer shall assign a unique identifying name or number to the plan of remedial measures.

6.5.1. A description of each vehicle type included in the plan of remedial measures;

6.5.2. A description of the specific modifications, alterations, repairs, corrections, adjustments, or other changes to be made to bring the vehicles into conformity including a brief summary of the data and technical studies which support the manufacturer's decision as to the particular measures to be taken to correct the non-conformity;

6.5.3. A description of the method by which the manufacturer informs the vehicle owners;

6.5.4. A description of the proper maintenance or use, if any, which the manufacturer stipulates as a condition of eligibility for repair under the plan of remedial measures, and an explanation of the manufacturer's reasons for imposing any such condition. No maintenance or use conditions may be imposed unless it is demonstrably related to the non-conformity and the remedial measures;

6.5.5. A description of the procedure to be followed by vehicle owners to obtain correction of the non-conformity. This shall include a date after which the remedial measures may be taken, the estimated time for the workshop to perform the repairs and where they can be done. The repair shall be done expediently, within a reasonable time after delivery of the vehicle;

6.5.6 A copy of the information transmitted to the vehicle owner;

6.5.7. A brief description of the system which the manufacturer uses to assure an adequate supply of component or systems for fulfilling the remedial action. It shall be indicated when there will be an adequate supply of components or systems to initiate the campaign;

6.5.8. A copy of all instructions to be sent to those persons who are to perform the repair;

6.5.9. A description of the impact of the proposed remedial measures on the emissions, fuel consumption, derivability, and safety of each vehicle type, covered by the plan of remedial measures with data, technical studies, etc. which support these conclusions;

6.5.10. Any other information, reports or data the Test Agency may reasonably determine is necessary to evaluate the plan of remedial measures.

6.5.11. Where the plan of remedial measures includes a recall, a description of the method for recording the repair shall be submitted to the Test Agency. If a label is used, an example of it shall be submitted.

6.6. The manufacturer may be required to conduct reasonably designed and necessary tests on components and vehicles incorporating a proposed change, repair, or modification to demonstrate the effectiveness of the change, repair, or modification.

6.7. The manufacturer is responsible for keeping a record of every vehicle recalled and repaired and the workshop which performed the repair. Test Agency shall have access to the record on request for a period of 5 years from the implementation of the plan of remedial measures.

6.8. The repair and/or modification or addition of new equipment shall be recorded in a certificate supplied by the manufacturer to the vehicle owner.

CHAPTER 18 - APPENDIX 2

STATISTICAL PROCEDURE FOR TAILPIPE EMISSIONS IN-SERVICE CONFORMITY TESTING

1.0 This Appendix describes the procedure to be used to verify the in-service conformity requirements for the Type I test.

2.0 Two different procedures are to be followed:

(a) One dealing with vehicles identified in the sample, due to an emission related defect, causing outliers in the results (clause 3 of this Appendix);

(b) The other deals with the total sample (clause 4 of this Appendix).

3.0 Procedure to be followed with outlying emitters in the sample

3.1. With a minimum sample size of three and a maximum sample size as determined by the procedure of clause 4 of this Appendix, a vehicle is taken at random from the sample and the emissions of the regulated pollutants are measured to determine if it is an outlying emitter.

3.2. A vehicle is said to be an outlying emitter when the conditions given in clause 3.2.1 below are met.

3.2.1. An outlying emitter is a vehicle where the applicable limit value as indicated for Type I test for any regulated pollutant is exceeded by a factor of 1.5.

3.2.2. In the specific case of a vehicle with a measured emission for any regulated pollutant within the 'intermediate zone' (For any vehicle, the 'intermediate zone' is determined as follows:

The vehicle shall meet the conditions given in clause 3.2.1. of this Appendix and, in addition, the measured value for the same regulated pollutant shall be below a level that is determined from the product of the same limit value for Type I test clause 5.3.1.4 of Chapter 1 of this Part multiplied by a factor of 2.5).

3.2.2.1. If the vehicle meets the conditions of this clause, the cause of the excess emission shall be determined and another vehicle is then taken at random from the sample.

3.2.2.2. Where more than one vehicle meets the condition of this clause, the Test Agency and the manufacturer shall determine if the excess emission from both vehicles is due to the same cause or not.

3.2.2.2.1. If the Test Agency and the manufacturer both agree that the excess emission is due to the same cause, the sample is regarded as having failed and the plan of remedial measures outlined in clause 6.0 of Appendix 1 of this Chapter applies.

3.2.2.2.2. If the Test Agency and the manufacturer cannot agree on either the cause of the excess emission from an individual vehicle or whether the causes for more than one vehicle are the same, another vehicle is taken at random from the sample, unless the maximum sample size has already been reached.

3.2.2.3. When only one vehicle meeting the conditions of this clause has been found, or when more than one vehicle has been found and the Test Agency and the manufacturer agree it is due to different causes, another vehicle is taken at random from the sample, unless the maximum sample size has already been reached.

3.2.2.4. If the maximum sample size is reached and not more than one vehicle meeting the requirements of this clause has been found where the excess emission is due to the same cause, the sample is regarded as having passed with regard to the requirements of clause 3 of this Appendix.

3.2.2.5. If, at any time, the initial sample has been exhausted, another vehicle is added to the initial sample and that vehicle is taken.

3.2.2.6. Whenever another vehicle is taken from the sample, the statistical procedure of clause 4 of this Appendix is applied to the increased sample.

3.2.3. In the specific case of a vehicle with a measured emission for any regulated pollutant within the 'failure zone' (For any vehicle, the 'failure zone' is determined as follows: The measured value for any regulated pollutant exceeds a level that is determined from the product of the limit value for the same regulated pollutant given in Type I test clause 5.3.1.4 of Chapter 1 of this Part multiplied by a factor of 2.5).

3.2.3.1. If the vehicle meets the conditions of this clause, the Test Agency shall determine the cause of the excess emission and another vehicle is then taken at random from the sample.

3.2.3.2. Where more than one vehicle meets the condition of this clause, and the Test Agency determines that the excess emission is due to the same cause, the manufacturer shall be informed that the sample is regarded as having failed, together with the reasons for that decision, and the plan of remedial measures outlined in clause 6 of Appendix 1 of this Chapter applies.

3.2.3.3. When only one vehicle meeting the conditions of this clause has been found, or when more than one vehicle has been found and the Test Agency has determined that it is due to different causes, another vehicle is taken at random from the sample, unless the maximum sample size has already been reached.

3.2.3.4. If the maximum sample size is reached and not more than one vehicle meeting the requirements of this clause has been found where the excess emission is due to the same cause, the sample is regarded as having passed with regard to the requirements of clause 3 of this Appendix.

3.2.3.5. If, at any time, the initial sample has been exhausted, another vehicle is added to the initial sample and that vehicle is taken.

3.2.3.6. Whenever another vehicle is taken from the sample, the statistical procedure of clause 4 of this Appendix is applied to the increased sample.

3.2.4. Whenever a vehicle is not found to be an outlying emitter, another vehicle is taken at random from the sample.

3.3. When an outlying emitter is found, the cause of the excess emission shall be determined.

3.4. When more than one vehicle is found to be an outlying emitter, due to the same cause, the sample is regarded as having failed.

3.5. When only one outlying emitter has been found, or when more than one outlying emitter is found, but due to different causes, the sample is increased by one vehicle, unless the maximum sample size has already been reached.

3.5.1. When in the increased sample more than one vehicle is found to be an outlying emitter, due to the same cause, the sample is regarded as having failed.

3.5.2. When in the maximum sample size not more than one outlying emitter is found, where the excess emission is due to the same cause, the sample is regarded as having passed with regard to the requirements of clause 3 of this Appendix.

3.6. Whenever a sample is increased due to the requirements of clause 3.5 of this Appendix, the statistical procedure of clause 4 of this Appendix is applied to the increased sample.

4.0. PROCEDURE TO BE FOLLOWED WITHOUT SEPARATE EVALUATION OF OUTLYING EMITTERS IN THE SAMPLE.

4.1. With a minimum sample size of three the sampling procedure is set so that the probability of a batch passing a test with 40% of the production defective is 0.95 (producer's risk = 5%) while the probability of a batch being accepted with 75% of the production defective is 0.15 (consumer's risk = 15%).

4.2. For each of the pollutants given in the Type I test limit, the following procedure is used (see Figure 2 of this Appendix).

Where:

L = the limit value for the pollutant,

x_i = the value of the measurement for the i-th vehicle of the sample,

n = the current sample number.

4.3. The test statistic quantifying the number of non-conforming vehicles, i.e. $x_i > L$, is computed for the sample.

4.4. Then:

(a) If the test statistic does not exceed the pass decision number for the sample size given in Table 1 of this Appendix, a pass decision is reached for the pollutant;

(b) If the test statistic equals or exceeds the fail decision number for the sample size given in Table 1 of this Appendix, a fail decision is reached for the pollutant;

(c) Otherwise, an additional vehicle is tested and the procedure is applied to the sample with one extra unit.

In the following Table 1 of this Appendix the pass and fail decision numbers are computed in accordance with the International Standard ISO 8422:1991.

5.0. A sample is regarded as having passed the test when it has passed both the requirements of clauses 3 and 4 of this Appendix.

Table 1

Table for Acceptance/Rejection Sampling Plan by Attributes

Cumulative sample size (n)	Pass decision number	Fail decision number
3	0	-
4	1	-
5	1	5
6	2	6
7	2	6
8	3	7
9	4	8
10	4	8
11	5	9
12	5	9
13	6	10
14	6	11
15	7	11
16	8	12
17	8	12
18	9	13
19	9	13
20	11	12

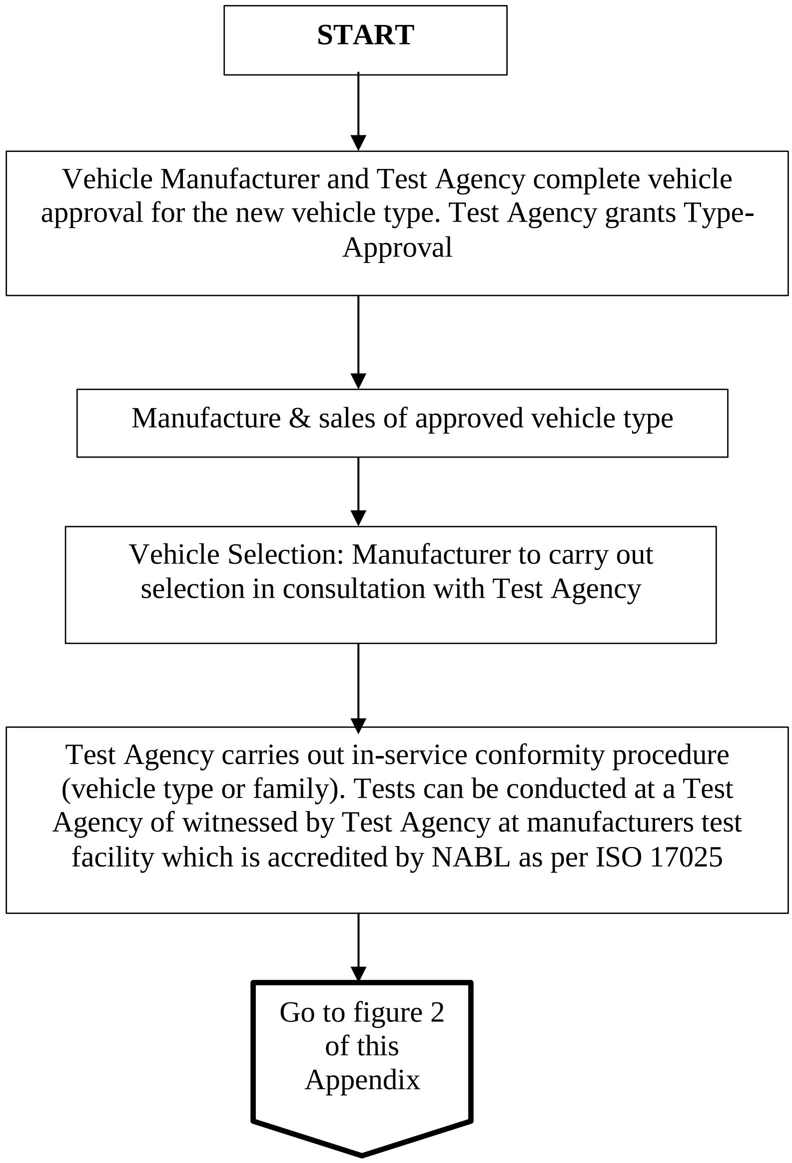
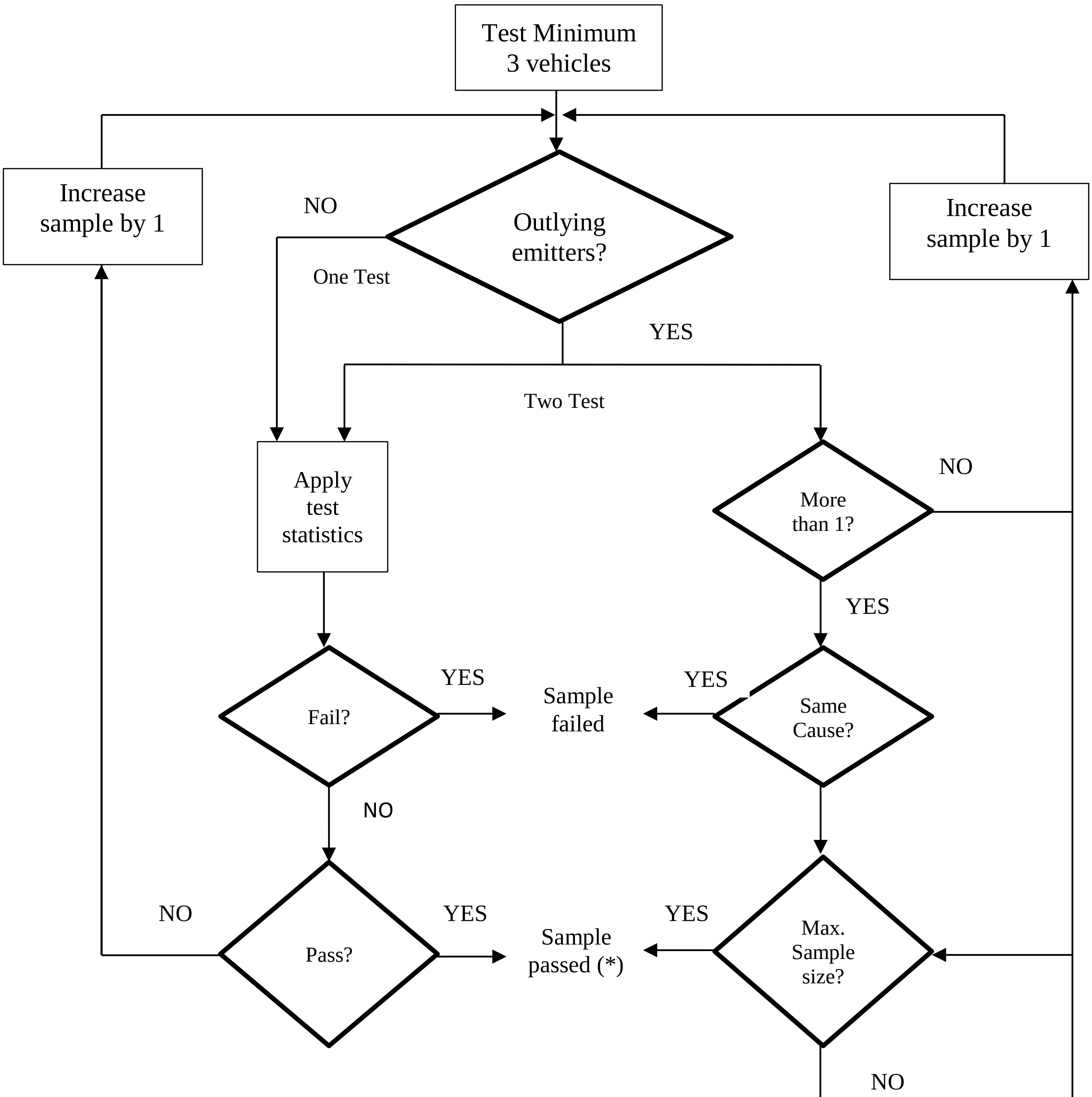


Figure 1
In-service Conformity Checking Procedure



(*) If it fulfils both texts.

Figure 2
In-service conformity testing – Selection and test of vehicles.

CHAPTER 18 - APPENDIX 3

RESPONSIBILITIES FOR IN-SERVICE CONFORMITY

1.0 The process of checking in-service conformity is illustrated in Figure 1 of this Appendix.

2.0 The manufacturer shall compile all the information needed to comply with the requirements of Appendices 1, 2 and 3 of this Chapter.

3.0 The Test Agency shall conduct all the procedures and tests necessary to ensure that the requirements regarding the in-service conformity are met (Phases 2 to 4).

4.0 In the event of discrepancies or disagreements in the assessment of information supplied, the Test Agency shall request clarification from the Test Agency that conducted the type approval test.

5.0 The manufacturer shall establish and implement a plan of remedial measures. This plan shall be approved by the Test Agency before it is implemented (Phase 5). Figure 1 of this Appendix is an illustration of the in-service conformity process.

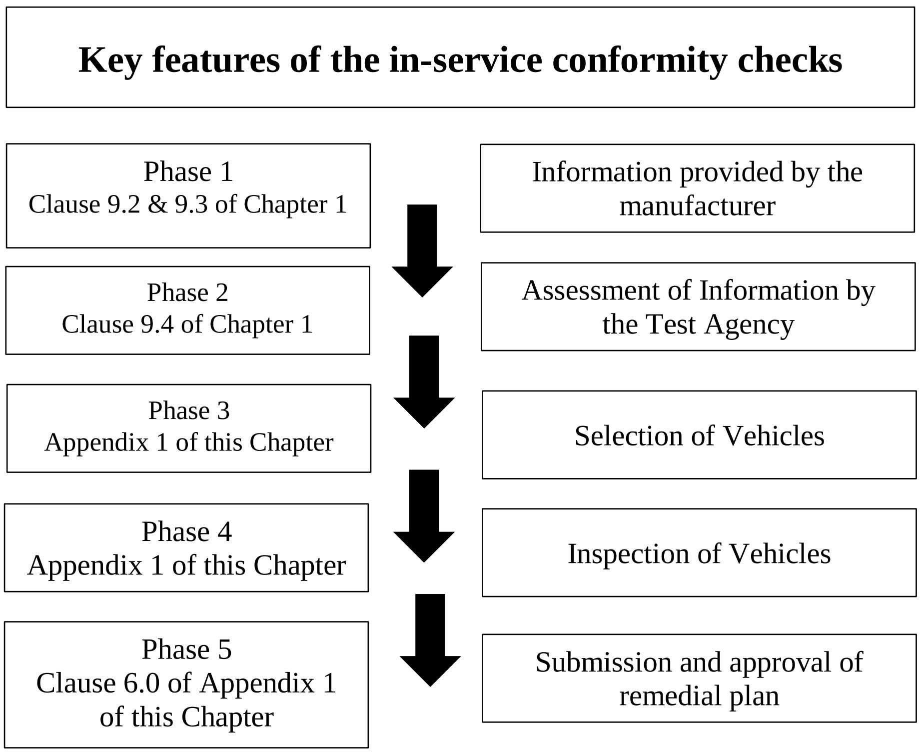


Figure 1
Illustration of the In-Service Conformity Process

CHAPTER 19

ADMINISTRATIVE AND TECHNICAL PROCEDURE FOR MEASUREMENT AND MONITORING [AVERAGE] FUEL CONSUMPTION IN L/100 km OF M1 CATEGORY VEHICLES WITH GVW NOT EXCEEDING 3500kg

1.0 INTRODUCTION

1.1 The Ministry of Road Transport and Highways (MoRTH) is the nodal authority for implementation of Fuel Consumption standards notified by Ministry of Power vide notification no. S.O. 1072(E) dated 23rd April, 2015. Accordingly, MoRTH has adopted this procedure under CMVR, 1989 vide notification no. G.S.R. 954(E) dated the 4th October, 2016, further amended by G.S.R 1461(E) dated 27th November, 2017.

1.2 The Fuel Consumption standards given in the said notification issued by Ministry of Power are in terms of Fuel Consumption in litre /100km. For the purpose of establishing compliance to these standards as per this procedure, these standards shall be converted into CO_2 g/km. Accordingly, for the purpose of this procedure the equation of the average fuel consumption standard (in litre/100km) given in the said notification issued by Ministry of Power as

a x (W-b) + c
is converted into CO_2 g/km as (a x (W-b) + c) * 23.7135

The values of “a”, “b”, “c” and “W” shall be as specified in the notification S.O. 1072(E) dated 23rd April, 2015, issued by Ministry of Power.

The compliance to the CO_2 equation mentioned here shall be deemed as compliance to the average fuel consumption standard in gasoline equivalent litre/100km given in the said notification issued by Ministry of Power.

1.3 In accordance with the MoRTH notification G.S.R. 954(E), dated the 4th October, 2016, further amended by G.S.R 1461(E) dated 27th November, 2017, this procedure specifies the technical and administrative details for monitoring the compliance to Fuel Consumption standards for M1 Category vehicles not exceeding 3.5 tons GVW tested on Chassis dynamometer subjected to type approval as per CMVR, 1989.

2.0 SCOPE

2.1 This procedure will be applicable to M1 Category vehicles not exceeding 3,500 kg GVW.

2.2 Following vehicles are exempted from applicability of this procedure:

2.2.1 **“Invalid Carriage”** as defined in The Motor Vehicles Act 1988, Chapter 1, Section 2 (18).

2.2.2 **“Special purpose vehicle (SPV)”** as defined in AIS-053:2005, as amended from time to time.

2.2.3 Vehicles exempted by Government of India from type approval for compliance to CMVR, 1989.

3.0 DEFINITIONS

For the purpose of this procedure, following definitions shall apply :

3.1 **“Manufacturer”** means an organization who is engaged in the manufacture and/or import of motor vehicles which are subjected to type approval and intended for domestic sale.

3.2 **“Corporate Group”** would mean and include manufacturers belonging to the same corporate group, as defined by minimum 51% direct shareholding in each manufacturing company by the corporate group, may be considered as one “Manufacturer” for the purpose of complying with fuel consumption standard.

3.3 **“Reporting period”** is a twelve month period starting from 1st April to 31st March of the following year, both dates inclusive.

3.4 **“Assessment year”** is the year after reporting period, during which the complied data is verified and reported to MoRTH and Ministry of Power / BEE.

3.5 **“Volume (n_i)”** is the total number of manufactured / imported vehicles of a type approved model ‘i’, including its variant(s) in a reporting period as declared by the manufacturer for which excise duty or GST /customs duty has been paid.

3.6 **“Designated Agency”** is the agency designated for collection, examination and reporting of data submitted by vehicle manufacturers, ref. notification no. G.S.R. 954(E), dated 4th October, 2016, further amended by G.S.R 1461(E) dated 27th November, 2017. As per notification, ICAT, Manesar is the Designated Agency.

3.7 **“Annual Fuel Consumption Report”** is the report to be submitted for every reporting period by the manufacturer to the Designated Agency in the specified format as per Appendix 1 and Appendix 2 of this Chapter.

3.8 **"Annual Fuel Consumption Compliance Report"** is the report for every reporting period submitted to MoRTH by the Designated Agency as per the format given in Appendix 4 of this Chapter.

3.9 **"Manufacturer Declared CO_2 (p_i)"** for a model 'i' and its variant(s) is the specific emission of CO_2 in g/km declared by a manufacturer and verified during type approval.

3.10 **"Petrol Equivalent Fuel Consumption (FC_i)"** for a model 'i' and its variant(s) is the petrol equivalent fuel consumption in litre/100km of a model 'i' and its variants(s).

It is equal to Manufacturer's Declared CO_2 value in g/km divided by 23.7135

3.11 **"Volume derogation factor for super-credits (vi)"** shall be the factor as per clause 6.1 of this Chapter.

3.12 **"CO_2 reducing technology derogation factor (c_i)"** shall be as per clause 6.2 of this Chapter.

3.13 **"Rules"** means the Central Motor Vehicles Rules ,1989.

3.14 **"Annual Corporate Average CO_2 Performance (P)"**, in relation to a manufacturer, means the weighted average CO_2 emissions of all said M1 Category vehicles not exceeding 3,500 kg GVW, manufactured/ imported during a reporting period.

It is expressed in g/km and rounded up to three decimal places.

3.15 **"Annual Corporate Average CO_2 Target (T)"**, in relation to a manufacturer, means the specific emissions of CO_2 permitted in respect of M1 Category vehicles not exceeding 3,500 kg GVW and is calculated in accordance with the clause 1.2 of this Chapter.

It is expressed in g/km and rounded up to three decimal places.

3.16 **"Small Volume Manufacturer"** is a manufacturer as defined in clause 3.1 of this Chapter, and whose manufactured / imported volume of all models and their variant(s) is less than 5,000 units in a reporting period (sales year) for M1 category vehicles not exceeding 3,500 kg GVW.

3.17 **"Zero (0) km vehicle"** means a vehicle that has covered the distance of less than or equal to 100 km before the start of preconditioning.

3.18 **"Hybrid Electric Vehicles (HEV)"** means a vehicle in which "power train" comprises a combination of two different drive train types:

- an internal combustion engine, and
- one (or several) electric drive train(s) HEV for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power:
- a consumable fuel • an electrical energy/power storage device (e.g.: battery, capacitor, flywheel/generator etc.)"

3.19 **"Strong Hybrid Electric Vehicle (Strong HEV)"** means a 'Hybrid Electric Vehicle (HEV)' which has a 'Stop-start' arrangement, 'Electric Regenerative braking system' and a 'Motor Drive' (motor alone is capable to propel the vehicle from a stationary condition).

3.20 **"Plug-in HEV (PHEV)/ Range Extended Electric Vehicle (REEV)"** means a 'Strong HEV' vehicle which has a provision for 'Off Vehicle charging' (OVC) of 'Rechargeable Energy Storage system (REESS)'.

3.21 **"Pure electric vehicle"** means vehicle powered by an electric power train only.

3.22 **"Bi Fuel"** means a vehicle that can run part-time on gasoline and also part-time on either LPG or NG.

4.0 CALCULATIONS, REPORTING AND COMPLIANCE VERIFICATION

4.1 Test Agencies, as notified under rule 126 of CMVR, 1989 shall provide all Type Approval (TA) and Conformity of Production (COP) emission test reports of M1 category vehicles for each reporting period to the Designated Agency.

4.2 Every manufacturer shall submit an **"Annual Fuel Consumption Report"** for the reporting period as per the format prescribed in Appendix 1 of this Chapter and "**Manufacturer's Fuel consumption Passbook"** as per format prescribed in Appendix 2 of this Chapter to the Designated Agency on or before 31st May of the Assessment year.

4.3 The Designated Agency shall examine and verify the manufacturer's data as submitted in Appendix 1 and Appendix 2 of this Chapter and shall inform any discrepancies observed regarding the details and calculations to the manufacturer on or before 20th June of the Assessment year.

4.4 In case manufacturer receives information about any discrepancies in its Annual Fuel Consumption Report, the manufacturer shall clear all those discrepancies on or before 10th July of the Assessment year.

4.5 The Designated Agency shall issue a "**STATUS OF COMPLIANCE"** to the manufacturer as per the format prescribed in Appendix 3 of this Chapter on or before 31st July of the Assessment year along with the copy of **Annual Fuel Consumption Report** (Appendix 1 of this Chapter) and **Manufacturer's Fuel Consumption Passbook** (Appendix 2 of this Chapter).

4.6 Designated agency shall compile all the information and submit the **"Annual Fuel Consumption Compliance Report**" to MoRTH and Ministry of Power/BEE on or before 31st August of each Assessment year as per format prescribed in Appendix 4 of this Chapter.

5.0 CO_2 CREDITS & DEBITS

5.1 The manufacturer's annual corporate average CO_2 performance (P) with respect to the target (T) can be quantified in terms of CO_2 credits / debits in metric tons/km and calculated as follows.

CO_2 Credits = $\{(T - P) X \Sigma n_i\}/10^6$

CO_2 Debits = $\{(P - T) X \Sigma n_i\}/10^6$

Where:

'P' is the manufacturer's annual corporate average CO_2 performance expressed in g/km

'T' is the manufacturer's annual corporate average CO_2 target expressed in g/km

n_i is the total number of vehicles manufactured / imported in India of a model 'i', including its variant(s) in a Reporting period for sale in India.

These credits and debits shall be recorded in the Manufacturer's fuel consumption passbook and may be used for any management purposes by the nodal agency.

6.0 SUPER CREDITS AND CO_2 REDUCING TECHNOLOGIES

6.1 SUPER CREDITS

a) For the purpose of calculating the Corporate Average CO_2 Performance (P), a manufacturer may consider using the volume derogation factor given below, for each of its models:

S. No.	Vehicle Type	Volume derogation factor for super credit (v_i)
1	Strong Hybrid Electric Vehicles	2.0
2	Plug-in Hybrid Electric Vehicles / Range Extender Hybrid Electric Vehicles	2.5
3	Pure Electric Vehicles	3.0

The effective Volume (N_i) of a model 'i' and its variant(s) shall be calculated as below :

$N_i = v_i \times n_i$

CO_2 emissions of vehicle models 'i' and its variant(s) of Pure Electric Vehicles shall be calculated as per the formula mentioned below:

CO_2 (g/km) = (FC in kWh/100 km) x 0.1028 x 23.7135

The above super credits will be reviewed and finalized by 1st Oct 2018 for 2022-2023 onward norms.

6.2 CO_2 REDUCING TECHNOLOGIES

6.2.1 The vehicle manufacturer, may use the following factors for the following CO_2 reducing technologies in calculating the Corporate Average CO_2 Performance (P).

These technologies shall be verified as per Appendix 5 of this Chapter and captured in technical specification AIS-007 and test report issued by the Type approval test agency during the type approval process.

CO_2 Reducing Technologies	**CO_2 reducing technology derogation factor on CO_2 emission (c_i)**
Regenerative braking	0.98
Start-Stop System*	0.98
Tyre pressure monitoring system	0.98
6 or more Speed Transmission	0.98

The technology factor for vehicles using multiple technologies shall be the multiplication of individual factors.

The CO_2 performance (P_i) of a model 'i' and its variants shall be calculated as below –

$P_i = c_1 \times c_2 \times \ldots\ldots \times c_n \times p_i$

*For reporting FY 17-18: Start – Stop system with manual intervention will be considered for fuel consumption computation.

6.2.2 For CO_2 reducing technologies other than those covered in 6.2.1 of this Chapter, the manufacturer shall demonstrate the savings to the Type Approval Agency. These CO_2 reducing technologies shall not be completely driver dependent and must achieve minimum reduction of 1 gm CO_2/ km.

While demonstrating the CO_2 savings on chassis dynamometer, a comparison should be made between the same vehicles with and without the CO_2 reducing technologies. The testing methodology should provide verifiable, repeatable and comparable measurements.

On satisfactory demonstration of savings using a technology or a combination of technologies, the Test Agency shall certify the savings from the said technology or the combination of technologies.

The CO_2 savings may be certified as a factor ranging from 0 to 1 or in absolute terms i.e. in g/km, as per the discretion of Test Agency

In case, the CO_2 savings of a technology or a combination of technologies has been already certified elsewhere, the demonstration may be on the basis of appropriate documentation supporting the manufacturer's claim. In such a case, the Test Agency will have the right to decide on the adequacy / appropriateness of the documentation submitted by the manufacturer, or else, may ask for demonstration using suitable test methodology.

Manufacturer may use the certified savings for calculation of its performance (P_i) for each model using the specific technology.

6.2.3 Provided no vehicle model 'i', including its variant(s) in each reporting period shall reduce more than 9.0 g/km of CO_2 for calculating purposes, for the technologies mentioned in 6.2.1 and 6.2.2 of this Chapter to be used for reducing CO_2 in that model.

7.0 VERIFICATION OF DECLARED VALUE

7.1 Test procedure:

7.1.1 The prototype vehicle shall be tested following the procedure for emission measurement prescribed in this Part or any other standard as may be notified by MoRTH.

7.1.2 The criteria for carrying out tests shall be same as those prescribed for the mass emission tests of the prevalent emission regulations.

For hybrid electric vehicles with a special gear shifting strategy, the gear shifting points prescribed in clause 5.2.1 of Chapter 3 of this Part are not applied. For these vehicles the driving cycle specified in clause 5.2.2 of Chapter 3 of this Part

Concerning gear shifting points, these vehicles shall be driven according to the manufacturer's instructions, as incorporated in the Owner's Manual and service/workshop manual of vehicles and indicated by a technical gear shift instrument.

7.1.3 For bi-fuel vehicles, CO_2 value of gaseous mode test shall be considered for calculation purpose.

7.1.4 In case of multiple modes, where default mode is –

7.1.4.1 available, tests shall be carried out in default mode.

7.1.4.2 not available, tests shall be carried out in all the modes. The maximum CO_2 value will be considered for the purpose of fuel consumption computation.

7.2 The CO_2 value (p_i) adopted as the type approval value shall be the value declared by the manufacturer, if the value measured as per 7.1.1 of this Chapter, does not exceed the declared value by more than four per cent. The measured value can be lower without any limitations.

7.3 If the measured value of CO_2 exceeds the manufacturer's declared CO_2 by more than 4 per cent, additional test shall be run on the same vehicle.

7.4 When the average of the two test results does not exceed the manufacturer's declared value by more than four per cent, then the value declared by the manufacturer is considered as the type approval value.

7.5 If the average still exceeds the declared value by more than four per cent, a final test is run on the same vehicle. The average of the three test results is considered as the type approval value.

7.6 During the process of 7.2 to 7.5 of this Chapter the manufacturer may modify the declared value. If the revised declared value complies with any of the conditions prescribed, additional tests prescribed above need not carried out.

7.7 The test agency shall issue a compliance test report to the manufacturer. The test report shall contain following:

(a) The final type approved value expressed as carbon dioxide emissions in g/km rounded to the third decimal place.

(b) Fuel consumption in l/100km calculated from final type approved value (mentioned in (a) above) using conversion factors provided in said notification, round to the third decimal place.

(c) The actual fuel consumption and gasoline equivalent fuel consumption (FC_i) in l/100km is calculated based on the formulae provided in the said notification, rounded to the third decimal place.

8.0 VARIANT (S) MANAGEMENT

8.1 All the model (s) / variant (s) included as one model for the purpose of CO_2 regulation:

(a) Shall have the same declared value.

(b) In case more than one test is required for type approval, all the test results shall be within the permitted tolerance of the declared value.

(c) Manufacturer shall have a system of establishing the production numbers. It is not necessary to account for the variants separately.

(d) One CMVR certificate may have more than one declared values of CO_2. However during reporting period, number of vehicles manufactured shall be identified separately.
Note: Separate COP for CO_2 will be conducted for variants having different manufacturer declared CO_2 values.

(e) In case of inertia class increases, the type approval can be extended to the higher inertia variant / model if the CO_2 emissions, as tested by the test agency, do not exceed the declared type approved value by more than four per cent.

(f) In case of 4x2 & 4x4 vehicles as variants, if declared CO_2 is

- same for both 4x4 & 4x2, test will be carried out in 4X4 variant.
- is different for 4x4 & 4x2 variants, test will be carried out on both variants.

However, for vehicle model having a selectable option for 4x2 & 4x4 modes, test will be carried out in 4x2 mode unless opted otherwise by the vehicle manufacturer.

The vehicle manufacturer shall comply to the following conditions w.e.f reporting period FY 19-20, in case test is carried out in 4x2 mode:

1. To adequately cover the adverse effects such as excessive noise, abnormal tyre wear, adverse fuel economy etc of the usage of 4x4 mode while normal driving on dry hard surface in the owner's manual and it is also recommended to educate the customer at the point of sale.

2. To provide a tell-tale symbol in the instrument cluster indicating the engagement of 4x4 mode.

8.2 Where different configurations of emission related components, necessitates different type approval test:

8.2.1 They may be treated as one model for CO_2 calculation, by the manufacturer provided conditions 8.1 (a) and (b) of this Chapter are satisfied.

8.2.2 If any such configuration (s) is/are to be treated as different model for CO_2 calculation, by the manufacturer, condition in clause 8.1(c) and (d) of this Chapter needs to be satisfied.

9.0 CONSEQUENCES OF:

A.: NON-SUBMISSION OF DATA
B.: NON-COMPLIANCE

A NON-SUBMISSION OF DATA

A.1 From the date of implementation, every manufacturer shall submit the Annual fuel consumption compliance report to the designated agency by 31st May following the reporting period.

A.2 It is the responsibility of every manufacturer to submit the Annual fuel consumption report to the designated agency by 31st May following the reporting period, failing which the designated agency shall report the matter to MoRTH and Ministry of Power/BEE for further suitable action against such manufacturers.

B NON-COMPLIANCE

B.1 From the date of implementation, every manufacturer shall maintain a fuel consumption passbook for continuously monitoring their corporate average fuel consumption including CO_2 credits and debits.

B.2 In case manufacturer does not comply with the requirements of MoRTH Fuel consumption Standard in the reporting period, the designated agency shall report such non-compliance to MORTH and Ministry of Power/BEE for further suitable action against such manufacturers.

10.0 CONFORMITY OF PRODUCTION

10.1 Vehicles approved to as per the procedure shall be so manufactured as to conform to the type approved vehicle.

10.1.1 The appropriate production checks shall be carried out to comply with the conditions in 10.1 of this Chapter.

Administrative Procedure for COP shall be applicable as per AIS-137 (Part 6)

10.2 The production of a series is regarded as conforming or non-conforming, on the basis of tests on the three sampled vehicles, once a pass or fail decision is reached for CO_2, according to the test criteria applied in the appropriate Table 1 of this Chapter. If no pass or fail decision is reached for CO_2, a test is carried out on an additional vehicle (see Figure 1 of this Chapter).

10.3 In the case of periodically regenerating systems (e.g. DPF), the results shall be multiplied by the factor Ki obtained by the procedure specified in relevant emission regulation at the time when type approval was granted. At the request of the manufacturer, testing may be carried out immediately after regeneration has been completed.

10.4 In case of multiple modes, where default mode is not available, COP shall be carried out on all the modes on one (01) sample.

10.5 CO_2 Reducing Technologies shall be verified by the test agency on the selected vehicles.

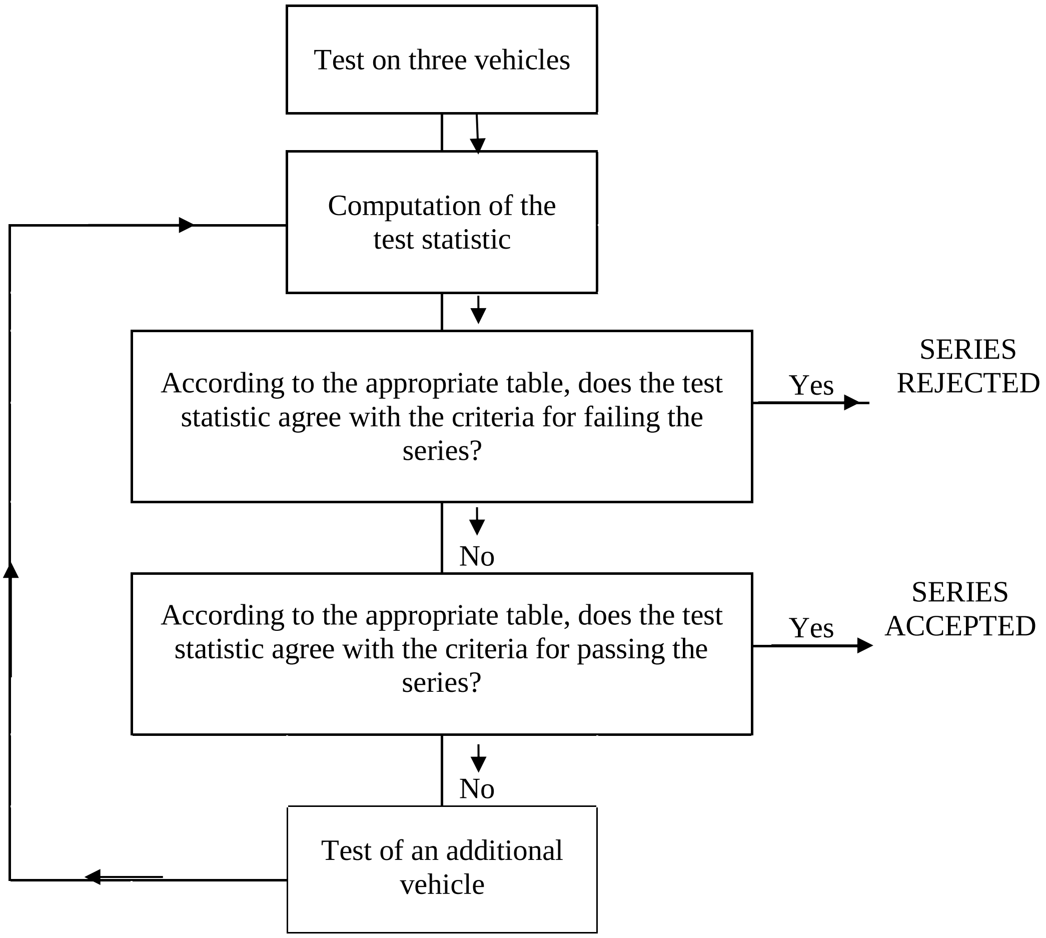


Figure 1

Note: Vehicle selection for compliance to Emission and Fuel Consumption COP shall be common, unless opted otherwise by the vehicle manufacturer, in which case, the compliance of both emission and CO_2 needs to be carried out simultaneously.

10.6 Notwithstanding the requirements of this Part , the tests will be carried out on zero km vehicles. However, during COP, the vehicle manufacturer has an option to select the method as per clause 10.6.1 or 10.6.2. of this Chapter. The compliance of both emission and CO_2 needs to be carried out simultaneously.

10.6.1 However, at the request of the manufacturer, the tests will be carried out on vehicles which have been run-in a maximum of 15,000 km.
In this case :

(a) The run-in procedure will be conducted by the manufacturer who shall undertake not to make any adjustments to those vehicles.

(b) The test result shall be multiplied by the Evolution Coefficient (EC) determined as follows:

- The emissions of CO_2 will be measured at zero and at 'x' km on the first tested vehicle (which can be the type approval vehicle);

- The evolution coefficient (EC) of the emissions between zero and 'x' km will be calculated as follows:

$$EC = \frac{Emissions\ at\ x\ km}{Emissions\ at\ zero\ km}$$

The value of EC may be less than 1.

The following vehicles will not be subjected to the running-in procedure, but their zero km emissions will be modified by the evolution coefficient, EC.

In this case, the values to be taken will be:

- The value at 'x' km for the first vehicle;
- The values at zero km multiplied by the evolution coefficient for the following vehicles.

10.6.2 As an alternative to this procedure, the manufacturer can use a fixed evolution coefficient, EC, of 0.92 and multiply all values of CO_2 measured at zero km by this factor.

10.7 Pass-Fail Criteria for COP

10.7.1 With a minimum sample size of three the sampling procedure is set so that the probability of a lot passing a test with 40 per cent of the production defective is 0.95 (producer's risk = 5 per cent) while the probability of a lot being accepted with 65 per cent of the production defective is 0.1 (consumer's risk = 10 per cent).

10.7.2 The measurement of CO_2 is considered to be log normally distributed and should first be transformed by taking the natural logarithms. Let m_o and **m** denote the minimum and maximum sample sizes respectively ($m_o = 3$ and $m = 32$) and let **n** denote the current sample number.

10.7.3 If the natural logarithms of the measurements in the series are x_1, x_2, ..., x_j and L is the natural logarithm of the CO_2 type approval declared value, then define:

$$d_j = X_j - L$$

$$\bar{d}_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^2 = \frac{1}{n}\sum_{j=1}^{n}\left(d_j - \bar{d}_n\right)^2$$

10.7.4 Table 1 of this Chapter shows values of the pass (A_n) and fail (B_n) decision numbers against current sample number. The test statistic is the ratio $\bar{d}_n / v_n$ and shall be used to determine whether the series has passed or failed as follows:

for $m_o \leq n \leq m$:

10.7.4.1 pass the series if $\bar{d}_n / v_n \leq A_n$;

10.7.4.2 fail the series if $\bar{d}_n / v_n \geq B_n$;

10.7.4.3 take another measurement if $A_n < \bar{d}_n / v_n < B_n$.

10.8 In case of low volume vehicles, if the number of a specific vehicle model and its variants produced/ Imported are less than 250 in any consecutive period of six months in a year, CO_2 COP should be carried out as per Figure 1 of this Chapter.

“Provided that in case the number of vehicles sold in India for a given base model and its variants (manufactured in India or imported to India) are less than 250 in any consecutive period of six months in a year, then such base model and its variants need not be subjected to the above test, if at least one model or its variants manufactured or imported by that manufacturer or importer, as the case may be, is subjected to such tests at least once in a year;

Provided further that, in case the number of base models and its variants manufactured / imported is more than one and if the individual base model and its variants are less than 250 in any consecutive period of six months in a year, then the testing agencies can pick up one of the vehicles out of such models and their variants for respective fuel type once in a year for carrying out such test”.

Note: The CO_2 values of such low volume vehicle models and their variants, when exempted from CO_2 COP, shall be taken from declared CO_2 value at the time of type approval for the purpose of Fuel consumption computations.

10.9 Consequences of COP Series Rejection

10.9.1 In case of series is rejected as during COP, the manufacturer shall change the "Manufacturers declared value". In such cases for the purpose of verification of manufactures re-declared CO_2 value, COP test result shall be considered.

10.10 Fuels: All tests shall be conducted with the reference fuel as specified in the applicable Gazette Notification. However, at the manufacturer's request, tests may be carried out with commercial fuel.

Table 1

Sample Size (cumulative number of vehicles tested), N	**Pass Decision No. A_n**	**Fail Decision No. B_n**
(a)	(b)	(c)
3	- 0.80380	16.64743
4	- 0.76339	7.68627
5	- 0.72982	4.67136
6	- 0.69962	3.25573
7	- 0.67129	2.45431
8	- 0.64406	1.94369
9	- 0.61750	1.59105
10	- 0.59135	1.33295
11	- 0.56542	1.13566
12	- 0.53960	0.97970
13	- 0.51379	0.85307
14	- 0.48791	0.74801
15	- 0.46191	0.65928
16	- 0.43573	0.58321
17	- 0.40933	0.51718
18	- 0.38266	0.45922
19	- 0.35570	0.40788
20	- 0.32840	0.36203
21	- 0.30072	0.32078
22	- 0.27263	0.28343
23	- 0.24410	0.24943
24	- 0.21509	0.21831
25	- 0.18557	0.18970
26	- 0.15550	0.16328
27	- 0.12483	0.13880
28	- 0.09354	0.11603
29	- 0.06159	0.09480
30	- 0.02892	0.07493
31	0.00449	0.05629
32	0.03876	0.03876

CHAPTR 19 - APPENDIX 1

ANNUAL FUEL CONSUMPTION REPORT TO BE SUBMITTED BY MANUFACTURER

Name and Address of the Manufacturer: -

Reporting Period: -------------

Serial No	Model (including variants and versions)	Type Approval Certificate number(s)	Unladen Mass (Wi) (kg)	Fuel	Manufac - turer declared CO_2 (pi) (g/km)	CO_2 Reducing Technology Factor (c_i)	CO_2 Performance of Model (including Variants and versions) (P_i)* p_i X c_i	Volume factor for Super Credit (v_i)	Manufac -tured / imported Volume (n_i)	Effective Volume (N_i) n_i X v_i	N_i X P_i	Wi X n_i
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
									Total			

*** Difference between p_i and P_i shall not be more than 9 g/km for a particular model.**

(A) Annual corporate average CO_2 emission performance and target

$P = \sum(N_i \times P_i) / \sum N_i$ = ------ g/Km

$T = (a * (W-b) + c)*23.7135$ (applicable as per clause 1.2 of this Chapter)
Where :

$W = \sum(n_i \times W_i) / \sum n_i$

Note : W_i (i.e. unladen mass in kg of a model **i**) is the heaviest mass of a type approved model and its variant(s) imported or in production for the reporting period.

For small volume manufacturers opting for alternate target, the target 'T' shall be calculated as given below:

Reporting period	Alternate annual corporate average CO_2 in g/km Target (T)
2017-18 onwards	P
2022-23	P * 0.830

Dated:

Authorized Signatory of Vehicle Manufacturer

CHAPTR 19 - APPENDIX 2

MANUFACTURER'S FUEL CONSUMPTION PASSBOOK

Name and Address of the Manufacturer: -

Reporting period (sales year): -------------

Reporting period	**Corporate average CO_2 target (T) (g/km)**	**Corporate average CO_2 performance (P) (g/km)**	**Manufactured / imported volume for the reporting period (Σ n_i)**	**CO_2 Credits earned (T-P)* Σ n_i/ 10^6 (t/km)**	**CO_2 Debits (P-T)* Σn_i/ 10^6 (t/km)**
(1)	(2)	(3)	(4)	(5)	(6)
2017-2018					
2018- 2019					
2019-2020					
And so on					

Dated: -

Authorized Signatory of Vehicle Manufacturer

CHAPTR 19 - APPENDIX 3

FORMAT OF COMPLIANCE

STATUS OF COMPLIANCE TO FUEL CONSUMPTION STANDARD

Based on the verification of the Appendix 1 and 2 of this Chapter, submitted by the manufacturer/ importer / corporate group / importers, M/s-------------------------------------, it is certified that the status of the Corporate Average Fuel Consumption for the fleet of vehicle models as given in the Appendix 1 as per the provisions of the Central Motor Vehicle Rules, 1989, under Rule 115 G, clause (2) ,for the reporting period starting from 1st April …… to 31st March ……… , is as given below.

Reporting Period	Credits	Debits	
FY (n)			
FY (n-1)			
FY (n-2)			
FY (n-3)			

Dated: -

Authorized Signatory ICAT, Manesar

CHAPTR 19 - APPENDIX 4

ANNUAL FUEL CONSUMPTION COMPLIANCE REPORT

Reporting period

Sr. No.	Manufacturer	Annual corporate average CO_2 (in g/km) performance (P)	CAFCS (= P/23.7135)	Manufacturer's annual corporate average CO_2 (in g/km) target (T)	ACAFC (= T/23.7135)	+ ve Credit / -ve Debit	Manufacturers Corporate Average CO_2 Compliance (Yes/No)
(1)	(2)	(3)	(4)	(5)	(6)	**(7)**	(8)
1	**Mfr1**						
2	**Mfr2**						
3	**Mfr3**						
4	**Mfr4**						

Dated: -

Authorized Signatory ICAT, Manesar

CHAPTR 19 – APPENDIX 5

DEFINITIONS FOR CO_2 REDUCTION TECHNOLOGIES

CO_2 reduction technology	Definition	Method of verification during type approval
Regenerative braking	A braking system, which during deceleration, provides for the conversion of vehicle kinetic energy into electrical energy.	Verify fitment of regenerative braking system as detailed by manufacture.
Start-Stop System	A system wherein during vehicle idling, the engine stops automatically and again starts automatically when operating conditions as defined by the vehicle manufacturer are met with.	Verify functionality by driving the vehicle. Start stop shall function as per system explanation / description of OEM.
Tyre pressure monitoring system	A system fitted on a vehicle, able to perform a function to evaluate the inflation pressure of the tyres or the variation of this inflation pressure over time and to transmit corresponding information to the user while the vehicle is running.	Verification of functionality that individual tyre pressures of all four wheels in-service, including the spare wheel (If regular in size), when in-service, are monitored and low pressure information is displayed on the dash board. This requirement does not apply to temporary spare wheel.
6 or more Speed Transmission	A transmission with provision of selecting 6 or more different gear ratios, which includes MT, AT, AMT, CVT types of transmission's, for the forward movement of vehicle.	Verify number of forward speed gears provided in vehicles (excluding reverse).

CHAPTER 19A

DETERMINATION OF THE EMISSIONS OF CARBON DIOXIDE, FUEL CONSUMPTION AND THE ELECTRIC ENERGY CONSUMPTION OF VEHICLES POWERED BY A HYBRID ELECTRIC POWER TRAIN

1.0 INTRODUCTION

1.1 This Chapter defines the specific provisions regarding type-approval of a Hybrid Electric Vehicle (HEV) as defined in clause 2.21.2 of Chapter 1 of this Part.

1.2 As a general principle for the tests, hybrid electric vehicles shall be tested according to the clause 1.2 of Chapter 17 of this Part unless modified by this Chapter.

1.3 OVC vehicles (as categorised in clause 2. of Chapter 17 of this Part shall be tested according to condition A and to condition B.

1.4 Driving cycles and gear shifting points are as per clause 3.1.2.5.3 of Chapter 17 of this Part.

2.0 Categories of hybrid electric vehicles is as defined in clause 2.0 of Chapter 17 of this Part.

3.0 EXTERNALLY CHARGEABLE (OVC HEV) WITHOUT AN OPERATING MODE SWITCH

3.1 Condition A

3.1.1 Tests to be performed as per clause 3.1.2 of Chapter 17 of this Part. Additionally following clauses to be considered.

3.1.1.1 Condition A :

End of charge criteria is defined as

The end of charge criteria corresponds to a charging time of 12 hours, except if a clear indication is given to the driver by the standard instrumentation that the electrical energy/power storage device is not yet fully charged.

In this case,

$$\text{the maximum time is} = \frac{3 * claimed\ battery\ capacity(Wh)}{mains\ power\ supply\ (W)}$$

3.1.1.2 **Condition A** : Test Procedure

Test procedure as described in clause 3.1.2.5 of Chapter 17 of this Part shall be followed and additionally the test results on the combined cycle (CO_2 and fuel consumption) for condition A shall be recorded (respectively m_1 (g) and c_1 (l)).

$$m_1 = \sum_{1}^{N} m_i \qquad c_1 = \sum_{1}^{N} c_i$$

In the case of testing according to clause 3.1.2.5.2.1. of Chapter 17 of this Part, (m_1) and (c_1) is simply the result of the single combined cycle run.

In the case of testing according to clause 3.1.2.5.2.2.of Chapter 17of this Part, m_1 and c_1 are the sums of the results of the N combined cycles run.

3.1.1.3 Within the 30 minutes after the conclusion of the last cycle, the electrical energy/power storage device shall be charged according to clause 3.1.2.4 of Chapter 17. The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_1 (Wh) delivered from the mains.

3.1.1.4 The electric energy consumption for condition A is e_1 (Wh).

3.2 **Condition B**

3.2.1 Conditioning of vehicle

3.2.1.1 The electrical energy/power storage device of the vehicle shall be discharged according to clause 3.1.3.2. of Chapter 17 of this Part. At the manufacturer's request, a conditioning according to clause 3.1.3.1.1 or 3.1.3.1.2. of Chapter 17 of this Part may be carried out before electrical energy / power storage discharge.

3.2.1.2 Before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least 6 h and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.

3.2.2 **Test Procedure**

3.2.2.1 Test procedure as described in clause 3.1.3.4 of Chapter 17 of this Part shall be followed and additionally the test results on the combined cycle (CO_2 and fuel consumption) for condition B shall be recorded (respectively m_2 (g) and c_2 (l)).

3.2.2.2 Within the 30 minutes after the conclusion of the last cycle, the electrical energy/power storage device shall be charged according to clause 3.1.2.4 of Chapter 17.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_2 (Wh) delivered from the mains.

3.2.2.3 The electrical energy/power storage device of the vehicle shall be discharged according to clause 3.1.2.1. of Chapter 17 of this Part

3.2.2.4 Within 30 minutes after the discharge, the electrical energy/power storage device shall be charged according to clause 3.1.2.4 of Chapter 17 of this Part.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_3 (Wh) delivered from the mains

3.2.2.5 The electric energy consumption e_4 (Wh) for condition B is:
$e_4 = e_2 – e_3$

3.3 Test Results

3.3.1 Test result to be calculated for CO_2 along with other pollutants according to clause 3.1.4 of Chapter 17 of this Part.

3.3.2 The values of fuel consumption shall be

$C_1 = 100 * c_1/D_{test1}$ and $C_2 = 100 * c_2/D_{test2}$ (l/100 km)

With D_{test1} and D_{test2} the total actual driven distances in the tests performed under conditions A (clause 3.1. of this Chapter) and B (clause 3.2. of this Chapter) respectively, and c_1 and c_2 determined in clause 3.1.1.2. and 3.2.2.1 of this Chapter respectively

3.3.3 The weighted values of fuel consumption shall be calculated as below

3.3.3.1 In the case of test procedure according to clause 3.1.2.5.2.1. of Chapter 17.

$C = (D_e * C_1 + D_{av} * C_2)/(D_e + D_{av})$

Where:

C = fuel consumption in l/100 km.

C_1 = fuel consumption in l/100 km with a fully charged electrical energy/power storage device.

C_2 = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_e = vehicle’s electric range, according to the procedure described in Appendix 2 of this Chapter, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

D_{av} = 25 km (assumed average distance between two battery recharges).

3.3.3.2 In the case of testing according to paragraph 3.1.2.5.2.2. of Chapter 17 of this Part.

$C = (D_{ovc} * C_1 + D_{av} * C_2)/(D_{ovc} + D_{av})$

Where:

C = fuel consumption in l/100 km.

C_1 = fuel consumption in l/100 km with a fully charged electrical energy/power storage device.

C_2 = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_{ovc} = OVC range according to the procedure described in Appendix 2 of this Chapter.

D_{av} = 25 km (assumed average distance between two battery recharges).

3.3.4 The values of electric energy consumption shall be:

$E_1 = e_1/D_{test1}$ and $E4 = e_4/D_{test2}$ (Wh/km)

With D_{test1} and D_{test2} the total actual driven distances in the tests performed under conditions A (clause 3.1. of this Chapter) and B (clause 3.2. of this Chapter) respectively,, and e1 and e4 determined in paragraphs 3.1.1.4. and 3.2.2.5 of this Chapter respectively

3.3.5 The weighted values of electric energy consumption shall be calculated as below:

3.3.5.1 In the case of testing according to clause 3.1.2.5.2.1. of Chapter 17 of this Part.

$E = (De * E_1 + D_{av} * E_4) / (D_e + D_{av})$

where:

E = electric consumption Wh/km.

E_1 = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated.

E_4 = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_e = vehicle's electric range, according to the procedure described in Appendix 2 of this Chapter, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

D_{av} = 25 km (assumed average distance between two battery recharges).

3.3.5.2 In the case of testing according to paragraph 3.1.2.5.2.2. of Chapter 17 of this Part.

$E = (D_{ovc} * E_1 + D_{av} * E_4) / (D_{ovc} + D_{av})$

Where:

E = electric consumption Wh/km.

E_1 = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated.

E_4 = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_{ovc} = OVC range according to the procedure described in Appendix 2 of this Chapter.

D_{av} = 25 km (assumed average distance between two battery recharges).

4.0 EXTERNALLY CHARGEABLE (OVC HEV) WITH AN OPERATING MODE SWITCH

4.0(A) In addition to the test procedure as described in clause 3.2 to 3.2.1.3 of Chapter 17 of this Part, following clauses to be considered.

4.1 **Condition A**

4.1.1 If the electric range of the vehicle, as measured in accordance with Appendix 2 of this Chapter, is higher than 1 complete cycle, on the request of the manufacturer, the Type I test for electric energy measurement may be carried out in pure electric mode, after agreement of the Test Agency. In this case, the values of M_1 and C_1 in clause 4.3. of this Chapter are equal to 0.

4.1.1.1 Condition A : Test Procedure

Test procedure as described in clause 3.2.2.2 to 3.2.2.7 of Chapter 17 of this Part shall be followed and additionally the test results on the combined cycle (CO_2 and fuel consumption) for condition A shall be recorded (respectively m_1 (g) and c_1 (l))

$$m_1 = \sum_{1}^{N} m_i \qquad c_1 = \sum_{1}^{N} c_i$$

In the case of testing according to clause 3.2.2.6.2.1. of Chapter 17 of this Part, (m_1) and (c_1) is simply the result of the single combined cycle run.

In the case of testing according to clause 3.2.2.6.2.2.of Chapter 17 of this Part, m_1 and c_1 are the sums of the results of the N combined cycles run.

4.1.1.2 Within the 30 minutes after the conclusion of the last cycle, the electrical energy/power storage device shall be charged according to clause 3.1.2.4 of Chapter 17 of this Part. The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_1 (Wh) delivered from the mains.

4.1.1.3 The electric energy consumption for condition A is e_1 (Wh).

4.2 **Condition B**

4.2.1 Conditioning of the vehicle

4.2.1.1 The electrical energy/power storage device of the vehicle shall be discharged according to clause 3.2.2.2 of Chapter 17 of this Part.

At the manufacturer's request, a conditioning according to clause 3.2.2.3.1 or 3.2.2.3.2 of Chapter 17 of this Part may be carried out before electrical energy / power storage discharge.

4.2.1.2 Before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 and 30 °C). This conditioning shall be carried out for at least 6 h and continue until the engine oil temperature and coolant, if any, are within ±2 K of the temperature of the room.

4.2.2 **Condition B : Test Procedure**

4.2.2.1 Test procedure as described in clause 3.2.3.4 of Chapter 17 of this Part shall be followed and additionally the test results on the combined cycle (CO_2 and fuel consumption) for condition B shall be recorded (respectively m_2 (g) and c_2 (l)).

4.2.2.2 Within the 30 minutes after the conclusion of the last cycle, the electrical energy/power storage device shall be charged according to clause 3.1.2.4 of Chapter 17 of this Part. The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_2 (Wh) delivered from the mains.

4.2.2.3 The electrical energy/power storage device of the vehicle shall be discharged according to clause 3.2.2.2 of Chapter 17 of this Part

4.2.2.4 Within 30 minutes after the discharge, the electrical energy/power storage device shall be charged according to clause 3.1.2.4 of Chapter 17 of this Part.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_3 (Wh) delivered from the mains

4.2.2.5 The electric energy consumption e_4 (Wh) for condition B is: $e_4 = e_2 – e_3$

4.3 **Test results**

4.3.1 Test result to be calculated for CO_2 along with other pollutants according to clause 3.2.4 of Chapter 17 of this Part.

4.3.2 The values of fuel consumption shall be

$C_1 = 100 * c_1/D_{test1}$ and $C_2 = 100 * c_2/D_{test2}$ (l/100 km)

With D_{test1} and D_{test2} the total actual driven distances in the tests performed under conditions A (clause 4.1. of this Chapter) and B (clause 4.2 of this Chapter) respectively, and c_1 and c_2 determined in clause 4.1.1.1 and 4.2.2.1 of this Chapter respectively

4.3.3 The weighted values of fuel consumption shall be calculated as below

4.3.3.1 In the case of test procedure according to clause 3.2.2.6.2.1. of chapter 17

$$C = (D_e * C_1 + D_{av} * C_2)/(D_e + D_{av})$$

Where:

C = fuel consumption in l/100 km.

C_1 = fuel consumption in l/100 km with a fully charged electrical energy/power storage device.

C_2 = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_e = vehicle's electric range, according to the procedure described in Appendix 2 of this Chapter, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

D_{av} = 25 km (assumed average distance between two battery recharges).

4.3.3.2 In the case of testing according to paragraph 3.2.2.6.2.2. of Chapter 17

$$C = (D_{ovc} * C_1 + D_{av} * C_2)/(D_{ovc} + D_{av})$$

Where:

C = fuel consumption in l/100 km.

C_1 = fuel consumption in l/100 km with a fully charged electrical energy/power storage device.

C_2 = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_{ovc} = OVC range according to the procedure described in Appendix 2 of this Chapter.

D_{av} = 25 km (assumed average distance between two battery recharges).

4.3.4 The values of electric energy consumption shall be:

$E_1 = e_1/D_{test1}$ and $E_4 = e_4/Dtest_2$ (Wh/km)

With D_{test1} and D_{test2} the total actual driven distances in the tests performed under conditions A (clause 4.1. of this Chapter) and B (clause 4.2. of this Chapter) respectively and e_1 and e_4 determined in paragraphs 4.1.1.3. and 4.2.2.5 of this Chapter respectively

4.3.5 The weighted values of electric energy consumption shall be calculated as below:

4.3.5.1 In the case of testing according to clause 3.2.2.6.2.1. of Chapter 17 of this Part.

$$E = (D_e * E_1 + Da_v * E_4) / (D_e + D_{av})$$

where:

E = electric consumption Wh/km.

E_1 = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated.

E_4 = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_e = vehicle's electric range, according to the procedure described in Appendix 2 of this Chapter, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

D_{av} = 25 km (assumed average distance between two battery recharges).

4.3.5.2 In the case of testing according to paragraph 3.2.2.6.2.2. of Chapter 17 of this Part.

$$E = (D_{ovc} * E_1 + D_{av} * E_4) / (D_{ovc} + D_{av})$$

Where:

E = electric consumption Wh/km.

E_1 = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated.

E_4 = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

D_{ovc} = OVC range according to the procedure described in Appendix 2 of this Chapter.

D_{av} = 25 km (assumed average distance between two battery recharges).

5.0 NOT EXTERNALLY CHARGEABLE (NOT-OVC HEV) WITHOUT AN OPERATING MODE SWITCH

5.1 Tests to be performed as per clause 3.3 of Chapter 17 of this Part. For vehicles with a special gear shifting strategy the gear shifting points prescribed in Chapter 3 of this Part is not applicable. For these vehicles the driving cycle specified in clause 5.2.2 of Chapter 3 of this Part shall apply. Concerning gearshift points, these vehicles shall be driven according to the manufacturer's instructions as incorporated in the drivers' handbook of production vehicles and indicated by technical gear shift instrument (for driver information)

Additionally following clauses to be considered

5.1.1 Emissions of carbon dioxide (CO_2) and fuel consumption shall be determined separately for the Part One (urban driving) and the Part Two (extra-urban driving) of the specified driving cycle.

5.2 **Test Results**

5.2.1 The test results (fuel consumption C (l/100 km) and CO_2-emission M [g/km]) obtained in clause 5.1 of this Chapter are corrected in function of the energy balance ΔEbatt of the vehicle's battery.

The corrected values (C_0 (l/100 km) and M_0 (g/km)) should correspond to a zero energy balance (ΔE_{batt} = 0), and are calculated using a correction coefficient determined by the manufacturer as defined below.

In case of other storage systems than an electric battery, ΔE_{batt} is representing $\Delta E_{storage}$, the energy balance of the electric energy storage device.

5.2.1.2 The electricity balance Q (Ah), measured using the procedure specified in Appendix 1 to this Chapter, is used as a measure of the difference in the vehicle battery's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined separately for the Part One cycle and the Part Two cycle.

5.2.2 Under the conditions below, it is allowed to take the uncorrected measured values C and M as the test results:

In case the manufacturer can prove that there is no relation between the energy balance and fuel consumption, In case that ΔE_{batt} always corresponds to a battery charging,

In case that ΔE_{batt} always corresponds to a battery decharging and ΔE_{batt} is within 1 per cent of the energy content of the consumed fuel (consumed fuel meaning the total fuel consumption over 1 cycle).

Energy content of the consumed fuel can be calculated from the following equation :
Total Fuel Energy (E_{fuel}) = $NHV_{fuel} * m_{fuel}$

Where,

NHV_{fuel} = Net heating value of consumable fuel in J/kg

m_{fuel} = Total mass of fuel consumed over one test cycle

The change in REESS energy content ΔE_{batt} can be calculated from the measured electricity balance Q as follows:

REESS depletion is considered as a negative current

$\Delta E_{batt} = \Delta SOC(\%) * E_{TEbatt} \approx 0.0036 * |\Delta Ah| * V_{batt} = 0.0036 * Q * V_{batt}$ (MJ)

with E_{TEbatt} (MJ) the total energy storage capacity of the battery and V_{batt} (V) the nominal battery voltage.

5.2.3 Fuel consumption correction coefficient (K_{fuel})

5.2.3.1 The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements. This set should contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$ and fulfil all criteria as per clause 5.2.5.1 of this Chapter.

5.2.3.2 The fuel consumption correction coefficient (K_{fuel}) is defined as

$$k_{fuel} = \frac{n * \Sigma Q_i C_i - \Sigma Q_i * \Sigma C_i}{n \Sigma Q_i^2 - (\Sigma Q_i)^2} \qquad \text{(1/100 Km /Ah)}$$

Where

C_i = fuel consumption measured during i-th test (l/100 km)

Q_i = electricity balance measured during i-th test (Ah)

n = number of data

The fuel consumption correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the fuel consumption correction coefficient is to be judged by the testing agency.

5.2.3.3 Separate fuel consumption correction coefficients shall be determined for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively

5.2.4 Fuel consumption at zero battery energy balance (C_0)

5.2.4.1 The fuel consumption C_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$C_0 = C - K_{fuel} * Q$ (l/100 km)

Where:

C = fuel consumption measured during test (l/100 km)

Q = electricity balance measured during test (Ah)

5.2.4.2 Fuel consumption at zero battery energy balance shall be determined separately for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively.

5.2.5 CO_2-emission correction coefficient (K_{CO2})

5.2.5.1 The correction coefficients CO_2-emission correction coefficient (K_{CO2}) shall be determined from a set of Type I tests according to clause 5.3 of this Chapter. The number of tests performed shall be equal to or greater than five.

The manufacturer may request to set the state of charge of the REESS prior to the test according to the manufacturer's recommendation and as described in clause 5.3 of this Chapter. This practice shall only be used for the purpose of achieving a charge-sustaining Type I test with opposite sign of the Qi and with approval of the Test Agency

The set of measurements shall fulfil the following criteria:

(a) The set shall contain at least one test with $Qi \leq 0$ and at least one test with $Qi > 0$.

(b) The difference in M_{CO2} between the test with the highest negative electric energy change and the test with the highest positive electric energy change shall be greater than or equal to 5 g/km.

In the case of the determination of K_{CO2}, the required number of tests may be reduced to three tests if all of the following criteria are fulfilled in addition to (a) and (b):

(c) The difference in M_{CO2} between any two adjacent measurements, related to the electric energy change during the test, shall be less than or equal to 10 g/km.

(d) In addition to (b), the test with the highest negative electric energy change and the test with the highest positive electric energy change shall not be within the region that is defined by:

$$-0.01 \leq \frac{\Delta E_{batt}}{E_{fuel}} \leq +0.01$$

where:

E_{fuel} is the energy content of the consumed fuel calculated according to clause 5.2.2 of this Chapter.

(e) The difference in M_{CO2} between the test with the highest negative electric energy change and the mid-point, and the difference in M_{CO2} between mid-point and the test with the highest positive electric energy change shall be similar and preferably be within the range defined by (d).

The correction coefficients determined shall be reviewed and approved by the test agency prior to its application.

If the set of at least five tests does not fulfil criterion (a) or criterion (b) or both, the manufacturer shall provide evidence to the Test Agency as to why the vehicle is not capable of meeting either or both criteria. If the test agency is not satisfied with the evidence, it may require additional tests to be performed. If the criteria after additional tests are still not fulfilled, the Test Agency will determine a conservative correction coefficient, based on the measurements.

5.2.5.2 The CO_2-emission correction coefficient (K_{CO2}) is defined as:

$K_{CO2} = (n * \Sigma Q_i M_i - \Sigma Q_i * \Sigma M_i) / (n * \Sigma Q_i^2 - (\Sigma Q_i)^2)$ (g/km/Ah)

Where:

M_i = CO_2-emission measured during i-th test (g/km)

Q_i = electricity balance during i-th test (Ah)

N = number of data

The CO_2-emission correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the CO_2-emission correction coefficient is to be judged by the Test Agency

5.2.5.3 Separate CO_2-emission correction coefficients shall be determined for the CO_2 emission values measured over the Part One cycle and the Part Two cycle respectively.

5.2.6 CO_2-emission at zero battery energy balance (M_0)

5.2.6.1 The CO_2-emission M_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$M_0 = M - K_{CO2} * Q$ (g/km)

Where:

M = CO_2 emission measured during test (g/km)

Q = electricity balance measured during test (Ah)

5.2.6.2 CO_2-emission at zero battery energy balance shall be determined separately for the CO_2-emission values measured over the Part One cycle and the Part Two cycle respectively.

5.3 Test procedure for the determination of the correction coefficients

5.3.1 For NOVC-HEVs, one of the following test sequences according to Figure 1 of this Chapter shall be used to measure all values that are necessary for the determination of the correction coefficients according to clause 5.2.4 and 5.2.5 of this Chapter

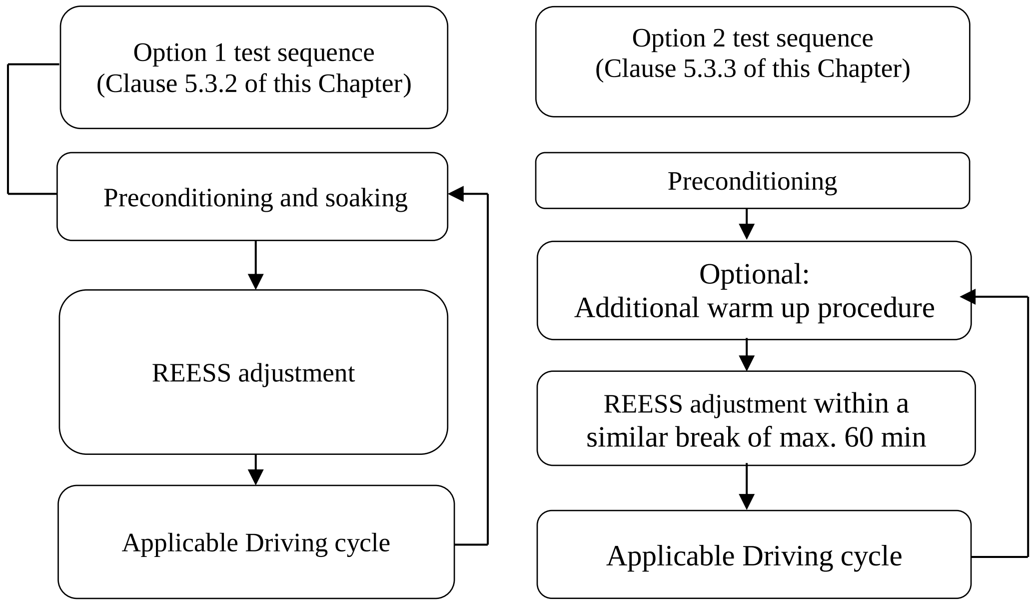


Figure 1
NOVC-HEV Test Sequences

5.3.2 **Option 1 test sequence**

5.3.2.1 Preconditioning and soaking

The test vehicle shall be preconditioned and soaked according to clause 3.3.2 of Chapter 17 of this Part.

5.3.2.2 REESS adjustment

Prior to the test procedure, according to clause 5.3.2.3 of this Chapter the manufacturer may adjust the REESS. The manufacturer shall provide evidence that the requirements for the beginning of the test according to clause 5.3.2.3 below of this Chapter are fulfilled

5.3.2.3 **Test procedure**

5.3.2.3.1 These vehicle shall be tested according to clause 3.3 of Chapter 17 of this Part.

5.3.2.3.2 To obtain a number of driving cycles that are required for the determination of the correction coefficients, the test can be followed by a number of consecutive sequences required according to clause 5.2.5.2 of this Chapter consisting as per clause 5.3.2.1 and 5.3.2.3 of this Chapter.

5.3.3 **Option 2 test sequence**

5.3.3.1 Preconditioning

The test vehicle shall be preconditioned and soaked according to clause 3.3.2 of Chapter 17 of this Part.

5.3.3.2 REESS adjustment

After preconditioning, the soaking shall be omitted and a break, during which the REESS is permitted to be adjusted, shall be set to a maximum duration of 60 minutes. A similar break shall be applied in advance of each test. Immediately after the end of this break, the requirements of clause 5.3.3.3 of this Chapter shall be applied.

Upon request of the manufacturer, an additional warm-up procedure may be conducted in advance of the REESS adjustment to ensure similar starting conditions for the correction coefficient determination. If the manufacturer requests this additional warm-up procedure, the identical warm-up procedure shall be applied repeatedly within the test sequence.

5.3.3.3 Test procedure

5.3.3.3.1 These vehicle shall be tested according to clause 3.3 of Chapter 17 of this Part.

5.3.3.3.2 To obtain a number of driving cycles that are required for the determination of the correction coefficients, the test can be followed by a number of consecutive sequences required according to clause 5.2.5.1 of this Chapter consisting as per clause 5.3.2.1 and 5.3.2.3 of this Chapter.

6.0 NOT EXTERNALLY CHARGEABLE (NOVC HEV) WITH AN OPERATING MODE SWITCH

6.1 Tests to be performed as per clause 3.4 of Chapter 17 of this Part. For vehicles with a special gear shifting strategy the gear shifting points prescribed in Chapter 3 of this Part is not applicable. For these vehicles the driving cycle specified in clause 5.2.2 of Chapter 3 of this Part shall apply. Concerning gearshift points, these vehicles shall be driven according to the manufacturer’s instructions as incorporated in the drivers’ handbook of production vehicles and indicated by technical gear shift instrument (for driver information)

Additionally following clauses to be considered

6.1.1 Emissions of carbon dioxide (CO_2) and fuel consumption shall be determined separately for the Part One (urban driving) and the Part Two (extra-urban driving) of the specified driving cycle.

6.2 **Test Results**

6.2.1 The test results (fuel consumption C (l/100 km) and CO_2-emission M [g/km]) of this test are corrected in function of the energy balance ΔEbatt of the vehicle's battery.

The corrected values (C_0 (l/100 km) and M_0 (g/km)) should correspond to a zero energy balance (ΔE_{batt} = 0), and are calculated using a correction coefficient determined by the manufacturer as defined below.

In case of other storage systems than an electric battery, ΔE_{batt} is representing $\Delta E_{storage}$, the energy balance of the electric energy storage device.

6.2.1.1 The electricity balance Q (Ah), measured using the procedure specified in Appendix 1 to this Chapter, is used as a measure of the difference in the vehicle battery's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined separately for the Part One cycle and the Part Two cycle.

6.2.2 Under the conditions below, it is allowed to take the uncorrected measured values C and M as the test results:

(1) In case the manufacturer can prove that there is no relation between the energy balance and fuel consumption,

(2) In case that ΔE_{batt} always corresponds to a battery charging,

(3) In case that ΔE_{batt} always corresponds to a battery decharging and ΔE_{batt} is within 1 per cent of the energy content of the consumed fuel (consumed fuel meaning the total fuel consumption over 1 cycle).

Energy content of the consumed fuel can be calculated from the following equation :

Total Fuel Energy (E_{fuel}) = NHVfuel * m_{fuel}

Where,

NHV_{fuel} = Net heating value of consumable fuel in J/kg

m_{fuel} = Total mass of fuel consumed over one test cycle

The change in REESS energy content ΔE_{batt} can be calculated from the measured electricity balance Q as follows:

REESS depletion is considered as a negative current

$\Delta E_{batt} = \Delta SOC(\%) * E_{TEbatt} \approx 0.0036 * |\Delta Ah| * V_{batt} = 0.0036 * Q * V_{batt}$ (MJ)

with E_{TEbatt} (MJ) the total energy storage capacity of the battery and V_{batt} (V) the nominal battery voltage.

6.2.3 Fuel consumption correction coefficient (K_{fuel})

6.2.3.1 The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements. This set should contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$ and fulfil all criaterias as per clause 6.2.5.1 of this chapter

6.2.3.2 The fuel consumption correction coefficient (Kfuel) is defined as

$$k_{fuel} = \frac{n * \Sigma Q_i C_i - \Sigma Q_i * \Sigma C_i}{n * \Sigma Q_i^2 - (\Sigma Q_i)^2} \qquad (1/100 \text{ Km /Ah})$$

where

C_i = fuel consumption measured during i-th test (l/100 km)

Q_i = electricity balance measured during i-th test (Ah)

n = number of data

The fuel consumption correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the fuel consumption correction coefficient is to be judged by the Test Agency.

6.2.3.3 Separate fuel consumption correction coefficients shall be determined for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively

6.2.4 Fuel consumption at zero battery energy balance (C_0)

6.2.4.1 The fuel consumption C_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$C_0 = C - K_{fuel} * Q$ (l/100 km)

Where:

C = fuel consumption measured during test (l/100 km)

Q = electricity balance measured during test (Ah)

6.2.4.2 Fuel consumption at zero battery energy balance shall be determined separately for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively.

6.2.5 CO_2-emission correction coefficient (K_{CO2})

6.2.5.1 The correction coefficients CO_2-emission correction coefficient (K_{CO2}) shall be determined from a set of Type I tests according to clause 5.3 of this Chapter. The number of tests performed shall be equal to or greater than five.

The manufacturer may request to set the state of charge of the REESS prior to the test according to the manufacturer's recommendation and as described in clause 5.3 of this Chapter. This practice shall only be used for the purpose of achieving a charge-sustaining Type I test with opposite sign of the Qi and with approval of the test agency

The set of measurements shall fulfil the following criteria:

(a) The set shall contain at least one test with $Qi \leq 0$ and at least one test with $Qi > 0$.

(b) The difference in M_{CO2} between the test with the highest negative electric energy change and the test with the highest positive electric energy change shall be greater than or equal to 5 g/km.

In the case of the determination of K_{CO2}, the required number of tests may be reduced to three tests if all of the following criteria are fulfilled in addition to (a) and (b):

(c) The difference in M_{CO2} between any two adjacent measurements, related to the electric energy change during the test, shall be less than or equal to 10 g/km.

(d) In addition to (b), the test with the highest negative electric energy change and the test with the highest positive electric energy change shall not be within the region that is defined by:

$$-0.01 \leq \frac{\Delta E_{batt}}{E_{fuel}} \leq +0.01$$

where:

E_{fuel} is the energy content of the consumed fuel calculated according to clause 5.2.2 of chapter.

(d) The difference in M_{CO2} between the test with the highest negative electric energy change and the mid-point, and the difference in M_{CO2} between mid-point and the test with the highest positive electric energy change shall be similar and preferably be within the range defined by (d).

The correction coefficients determined shall be reviewed and approved by the test agency prior to its application.

If the set of at least five tests does not fulfil criterion (a) or criterion (b) or both, the manufacturer shall provide evidence to the Test Agency as to why the vehicle is not capable of meeting either or both criteria. If the test agency is not satisfied with the evidence, it may require additional tests to be performed. If the criteria after additional tests are still not fulfilled, the Test Agency will determine a conservative correction coefficient, based on the measurements.

6.2.5.2 The CO_2-emission correction coefficient (K_{CO2}) is defined as:

$$K_{CO2} = (n * \Sigma Q_i M_i - \Sigma Q_i * \Sigma M_i) / (n * \Sigma Q_i^2 - (\Sigma Q_i)^2) \text{ (g/km/Ah)}$$

Where :

M_i = CO_2-emission measured during i-th test (g/km

Q_i = electricity balance during i-th test (Ah)

n = number of data

The CO_2-emission correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the CO_2-emission correction coefficient is to be judged by the Test Agency

6.2.5.3 Separate CO_2-emission correction coefficients shall be determined for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively.

6.2.6 CO_2-emission at zero battery energy balance (M_0)

6.2.6.1 The CO_2-emission M_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$$M_0 = M - K_{CO2} * Q \quad \text{(g/km)}$$

Where:

C = fuel consumption measured during test (l/100 km)

Q = electricity balance measured during test (Ah)

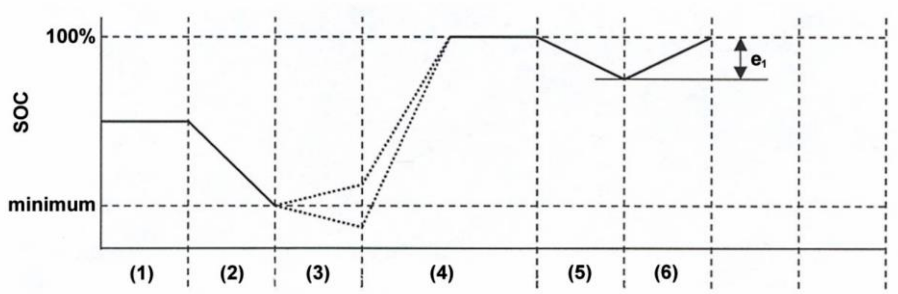
6.2.6.2 CO_2-emission at zero battery energy balance shall be determined separately for the CO_2-emission values measured over the Part One cycle and the Part Two cycle respectively.

CHAPTER 19A- APPENDIX 0

ELECTRICAL ENERGY/POWER STORAGE DEVICE STATE OF CHARGE (SOC) PROFILE FOR OVC HEVS

The SOC profiles for OVC-HEVs tested under Conditions A and B are:

Condition A:



(1) Initial state of charge of the electrical energy/power storage device

(2) Discharge

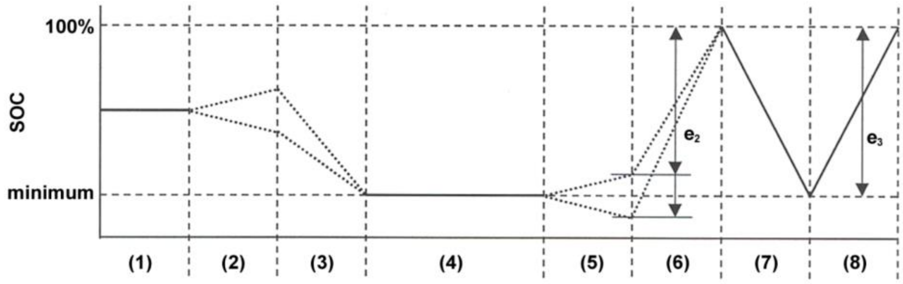
(3) Vehicle conditioning

(4) Charge during soak

(5) Test

(6) Charging

Condition B:



(1) Initial state of charge

(2) Vehicle conditioning

(3) Discharge

(4) Soak

(5) Test

(6) Charging

(7) Discharging

(8) Charging

CHAPTER 19A - APPENDIX 1

METHOD FOR MEASURING THE ELECTRICITY BALANCE OF THE BATTERY (REESS) OF OVC AND NOVC HEVS

1.0 INTRODUCTION

1.1 The purpose of this Appendix is to define the method and required instrumentation for measuring the electricity balance of Off-Vehicle Charging Hybrid Electric Vehicles (OVC HEV) and Not Off-Vehicle Charging Hybrid Electric Vehicles (NOVC HEVs). Measurement of the electricity balance is necessary

(a) To determine when the minimum state of charge of the battery has been reached during the test procedure defined in clause 3.1 and 3.2 of Chapter 17 of this Part.

(b) To correct the measured fuel consumption and CO_2-emissions for the change in battery energy content occurring during the test, using the method defined in in clause 3.3 and 3.4 of Chapter 17 of this Part.

1.2 The method described in this Appendix shall be used by the manufacturer for the measurements that are performed to determine the correction factors K_{fuel} and K_{C02} , as defined in clause 5.2.3.2., 5.2.5.2., 6.2.3.2., and 6.2.5.2. of this Chapter.

The Test Agency shall check whether these measurements have been performed in accordance with the procedure described in this Appendix.

1.3 The method described in this Appendix shall be used by the Test Agency for the measurement of the electricity balance Q, as defined in clause 3.1.1.2, 4.1.1.1., 5.2.4.1., 5.2.6.1., 6.2.4.1., and 6.2.6.1. of this Chapter.

2.0 MEASUREMENT EQUIPMENT AND INSTRUMENTATION

2.1 During the tests as described in clause 3., 4., 5. and 6. of this Chapter the battery current shall be measured using a current transducer of the clamp-on type or the closed type. The current transducer (i.e. the current sensor without data acquisition equipment) shall have a minimum accuracy of 0.5 per cent of the measured value (in A) or 0.1 per cent of the maximum value of the scale.

OEM diagnostic testers are not to be used for the purpose of this test.

2.1.1 The current transducer shall be fitted on one of the wires directly connected to the battery. In order to easily measure battery current using external measuring equipment, manufacturers should preferably integrate appropriate, safe and accessible connection points in the vehicle. If that is not feasible, the manufacturer is obliged to support the Test Agency by providing the means to connect a current transducer to the wires connected to the battery in the above described manner

2.1.2 The output of the current transducer shall be sampled with a minimum sample frequency of 5 Hz. The measured current shall be integrated over time, yielding the measured value of Q, expressed in Ampere hours (Ah).

2.1.3 The temperature at the location of the sensor shall be measured and sampled with the same sample frequency as the current, so that this value can be used for possible compensation of the drift of current transducers and, if applicable, the voltage transducer used to convert the output of the current transducer.

2.2 A list of the instrumentation (manufacturer, model no., serial No.) used by the manufacturer for determining:

(a) When the minimum state of charge of the battery has been reached during the test procedure defined in clause 3. and 4. of this Chapter and,

(b) The correction factors K_{fuel} and K_{CO2} (as defined in paragraphs 5.2.3.2., 5.2.5.2., 6.2.3.2., and 6.2.5.2. of this Chapter)

and the last calibration dates of the instruments (where applicable) should be provided to the Test Agency.

3.0 MEASUREMENT PROCEDURE

3.1 Measurement of the battery current shall start at the same time as the test starts and shall end immediately after the vehicle has driven the complete driving cycle

3.2 Separate values of Q shall be logged over the Part One and Part Two of the cycle.

CHAPTER 19A - APPENDIX 2

METHOD OF MEASURING THE ELECTRIC RANGE OF VEHICLES POWERED BY A HYBRID ELECTRIC POWER TRAIN AND THE OVC RANGE OF VEHICLES POWERED BY A HYBRID ELECTRIC POWERTRAIN

1.0 MEASUREMENT OF THE ELECTRIC RANGE

The test method described hereafter permits to measure the electric range, expressed in km, of vehicles powered by an electric power train only or the electric range and OVC range of vehicles powered by a hybrid electric power train with off-vehicle charging (OVC-HEV as defined in clause 2. of Chapter 17 of this Part).

2.0 PARAMETERS, UNITS AND ACCURACY OF MEASUREMENTS

Parameters, units and accuracy of measurements shall be as follows:

Parameter	Unit	Accuracy	Resolution
Time	s	+/-0.1 s	0.1 s
Distance	m	+/-0.1%	1 m
Temperature degrees	C	+/-1° C	1° C
Speed	km/h	+/-1 %	0.2 km/h
Mass	kg	+/-0.5 %	1 kg
Electricity balance	Ah	+/-0.5 %	0.3 %

3.0 TEST CONDITIONS

3.1 **Condition of the Vehicle**

3.1.1 The vehicle tyres shall be inflated to the pressure specified by the vehicle manufacturer when the tyres are at the ambient temperature.

3.1.2 The viscosity of the oils for the mechanical moving parts shall conform to the specifications of the vehicle manufacturer

3.1.3 The lighting and light-signalling and auxiliary devices shall be off, except those required for testing and usual daytime operation of the vehicle

3.1.4 All energy storage systems available for other than traction purposes (electric, hydraulic, pneumatic, etc.) shall be charged up to their maximum level specified by the manufacturer.

3.1.5 If the batteries are operated above the ambient temperature, the operator shall follow the procedure recommended by the vehicle manufacturer in order to keep the temperature of the battery in the normal operating range.

The manufacturer’s agent shall be in a position to attest that the thermal management system of the battery is neither disabled nor reduced

3.1.6 The vehicle must have undergone at least 300 km during the seven days before the test with those batteries that are installed in the test vehicle.

3.2 **Climatic Conditions**

For testing performed outdoors, the ambient temperature shall be between 5 °C and 32 °C.

The indoors testing shall be performed at a temperature between 20 °C and 30 °C.

4.0 OPERATION MODES

The test method includes the following steps:

(a) Initial charge of the battery;

(b) Application of the cycle and measurement of the electric range.

Between the steps, if the vehicle shall move, it is pushed to the following test area (without regenerative recharging).

4.1 **Initial Charge of the Battery**

Charging the battery consists of the following procedures:

Note: "Initial charge of the battery" applies to the first charge of the battery, at the reception of the vehicle. In case of several combined tests or measurements, carried out consecutively, the first charge carried out shall be an "initial charge of the battery" and the following may be done in accordance with the "normal overnight charge" procedure.

4.1.1 Discharge of the battery

4.1.1.1 For externally chargeable Hybrid Electric Vehicle (OVC HEV) without an operating mode switch as defined in this Chapter.

4.1.1.1.1 The manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state.

4.1.1.1.2 The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up;

(b) Or, if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run at a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer);

(c) Or with manufacturers' recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

4.1.1.2 For externally chargeable Hybrid Electric Vehicle (OVC HEV) with an operating mode switch as defined in this Chapter:

4.1.1.2.1 If there is not a pure electric position, the manufacturer shall provide the means for performing the discharge of the battery with the vehicle running in pure electric operating state.

4.1.1.2.2 The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 %+/-5 % of the maximum 30 minutes speed of the vehicle.

4.1.1.2.3 Stopping the discharge occurs:

(a) When the vehicle is not able to run at 65 % of the maximum 30 minutes speed; or

(b) When an indication to stop the vehicle is given to the driver by the standard onboard instrumentation; or

(c) After covering the distance of 100 km.

4.1.1.2.4 If the vehicle is not equipped with a pure electric operating state, the electrical energy/power storage device discharge shall be achieved by driving the vehicle (on the test track, on a chassis dynamometer, etc.):

(a) At a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up; or

(b) If a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine , the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between Test Agency and manufacturer); or

(c) With manufacturers' recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

4.1.2 Application of a normal overnight charge

For an OVC HEV, the battery shall be charged according to the normal overnight charge procedure as described in clause 3.1.1 of this Chapter.

4.2 Application of the cycle and measurement of the range

4.2.1 For Hybrid Electric Vehicles

4.2.1.1 To determine the electric range of a hybrid electric vehicle

4.2.1.1.1 The applicable test sequence and accompanying gear shift prescription, as defined in clause, 1.4 of this Chapter, is applied on a chassis dynamometer adjusted as described in Appendix 1 of Chapter 4, Appendix 1 and 2 of Chapter 5 of this Part.

To determine the electric range (D_e) of OVC HEVs equipped with an operating mode switch the same operating mode position, in accordance with clause 4.0 (A).and clause 4.1.1 of this Chapter, shall be used as for the determination of CO_2 and fuel consumption.

4.2.1.1.2 To measure the electric range the end of the test criteria is reached when the vehicle is not able to meet the target curve up to 50 km/h, or when an indication from the standard on-board instrumentation is given to the driver to stop the vehicle or when the battery has reached its minimum state of charge. Then the vehicle shall be slowed down to 5 km/h by releasing the accelerator pedal, without touching the brake pedal and then stopped by braking.

4.2.1.1.3 At a speed over 50 km/h, when the vehicle does not reach the required acceleration or speed of the test cycle, the accelerator pedal shall remain fully depressed until the reference curve has been reached again. The maximum possible speed in pure electric operating state in the first combined cycle shall be recorded in the test report and in the drivers' handbook of production vehicles.

During this procedure, the electricity balance (QES_i) of the high voltage battery (expressed in Ampere hours), measured continuously and using the procedure specified in Appendix 1 of Chapter 19A of this Part, the vehicle speed (VES_i) and De_i shall be recorded at the instant when the fuel consuming engine starts and the accumulation of Dei shall be stopped. Further accumulation of De_i shall not be permitted unless:

(a) The fuel consuming engine stopped running; and

(b) VES_i has returned to the same or any lower level of VES_i as recorded before the fuel consuming engine started; and

(c) QES_i has returned to the same or any lower level of QES_i as recorded before the last fuel consuming engine start or, where applicable, to the same or any lower level of QSA_i as determined in accordance with clause 4.2.1.1.3.1. of this Appendix.

This procedure shall be followed until the end of the test as defined in clause 4.2.1.1.2. of this Appendix.

4.2.1.1.3.1 During the first deceleration phase following each start of the fuel consuming engine, when the vehicle speed is less than the vehicle speed at which the fuel consuming engine started previously:

(a) The distance covered with engine off should be counted as D_{ei}; and

(b) The increase in electricity balance during this period should be recorded (ΔQrb_i); and

(c) The electricity balance when the fuel consuming engine starts (QES_i) defined previously should be corrected by ΔQrb_i (hence new $QSA_i = QES_i + \Delta Qrb_i$);

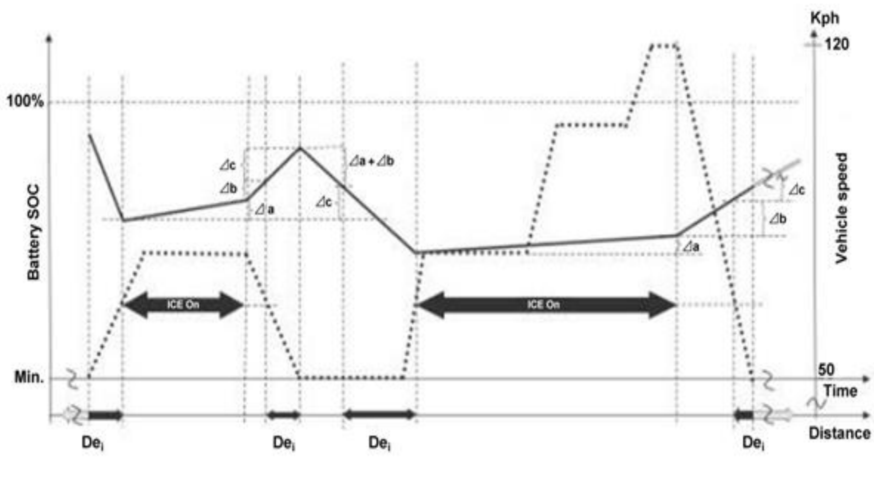
VES_i = Vehicle speed at the moment when the ICE starts;

QES_i = Energy of the battery at the moment when the ICE starts;

ΔQrb_i = The increase in electricity balance during deceleration phases, when the vehicle speed is less than the vehicle speed at which the ICE started previously;

QSA_i = Energy of the battery at the moment of the further accumulation of De.

Example :



⊿ a = Charged by ICE

⊿ b = Charged by regeneration (vehicle acceleration by ICE)

⊿ c = Charged by regeneration (ΔQrb_i, vehicle acceleration with energy from battery)

$De = \Sigma De_i$

De_i = Distances where the propulsive energy was not produced by ICE

__________ Battery SOC

………….. Vehicle Speed

4.2.1.1.4 To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total

4.2.1.1.5 At the end, the electric range is the sum of all cycle portions Dei in km. It shall be rounded to the nearest whole number.

4.2.1.2 To determine the OVC range of a hybrid electric vehicle

4.2.1.2.1 The applicable test sequence and accompanying gear shift prescription, as defined in in clause 1.4 of this Chapter, is applied on a chassis dynamometer.

4.2.1.2.2 To measure the OVC range the end of the test criteria is reached when the battery has reached its minimum state of charge according to the criteria defined in Chapter 17 to this Part, clause 3.1.1.2 and 4.1.1.1 of this Chapter. Driving is continued until the final idling period in the extra-urban cycle.

4.2.1.2.3 To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total.

4.2.1.2.4 At the end, the total distance driven in km, rounded to the nearest whole number, is the OVC range of the hybrid electric vehicle

CHAPTER 20

VERIFYING REAL DRIVING EMISSIONS
(Reserved – see introduction)

ANNEXURE 1

(See Introduction)

COMPOSITION OF A COMMITTEE FOR FORMULATION OF THIS STANDARD AS PER MORTH OFFICE MEMORANDUM NO. RT-11035/28/2015-MVL DATED 3rd SEPTEMBER, 2015

Chairperson	
Mrs. Rashmi Urdhwareshe	Director, The Automotive Research Association of India (ARAI), Pune
Co-ordinator and Member Secretary	
Mr. K. Srinivas	The Automotive Research Association of India (ARAI), Pune
Members	**Representing**
Representative from	International Centre for Automotive Technology (iCAT), Manesar, Gurgaon
Representative from	Society of Indian Automobile Manufacturers (SIAM), New Delhi
Representative from	Ministry of Petroleum & Natural Gas (MoPNG), New Delhi
Representative from	Emission Control Manufacturers Association (ECMA), New Delhi
Representative from	Automotive Components Manufacturers Association of India (ACMA), New Delhi
Representative from	Vehicles Research and Development Establishment (VRDE), Ahmednagar
Representative from	Central Institute of Road Transport (CIRT), Pune
Representative from	Indian Institute of Petroleum (IIP), Dehra Dun
Representative from	Ministry of Road Transport and Highways (MoRTH), New Delhi