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69th GRPE, 5 – 6 June 2014
Agenda item 3a

Snapshot of progress in the development of the EU UNECE WLTP.

Provided to the 69th GRPE June 2014 for information purposes.

Administrative Working Group (AdminWG) addressing the Implementation of the WLTP in EU Legislation

Document introduction / explanation

This document is a draft of the transposition of the WLTP GTR (Phase 1a) into EU and UN/ECE regulation.

In its current format the document is being prepared as if it will become a new annex (Annex XXI) to EU Regulation No 692/2008. Therefore the annexes in the GTR have been renamed as ‘sub-annexes’ for Annex XXI (this document).

The starting point (baseline) for the transposition is Part II of the WLTP GTR Benchmark (01.02.2014). All changes to the text of that document are shown as ‘tracked changes’. NB: formatting changes have been accepted for this version to make the document easier to read.

As well as the text changes that have been made relating to the transposition, the document also includes the editorial changes that have been made to the WLTP GTR in subsequent benchmark documents (04.03.2014 and 25.03.2014). The majority of these amendments have been made to the text, however some are included as comments at the relevant point in the document. These will be incorporated into the text (or not) following approval (or not) at the AdminWG.

The three main substantive areas where the EC & UN/ECE regulations will differ from the WLTP GTR relate to the introduction of ‘regional options’ for:

(i) Test cycle flexibilities (being developed by TUG and TNO);
(ii) Regional temperature corrections (being developed by Audi/BMW & PSA); and
(iii) HEV Utility Factors (being developed by ACEA).

It is currently the intention to include (i) and (ii) in a new Sub-Annex 10, with cross-references to that Sub-Annex from the relevant places in the other sections of Annex XXI. An early draft of the Regional temperature corrections (November 2013) is included in Sub-Annex 10.

The WLTP GTR already has a location for (iii) – this being Appendix 5 of Annex 8 (now Sub-Annex 8 in this document).

The document includes a range of comments. These relate to proposals for amendments, requirements for technical clarifications, future test reporting, and a range of other issues including minor editorial and formatting requirements.

R.Gardner, TRL. 28th March 2014.

Editing principles

Document retains the UNECE formatting principles

Cross-references that have been checked and verified as correct are highlighted in green

All references to “responsible authority” have been replaced with “approval authority”.

Document updated to take into account comments from the AdminWG meetings on 1st and 4th April 2014 and subsequent discussions with the WLTP GTR editing coordinator (Serge Dubuc).

R.Gardner. TRL. 11th April 2014.

This version includes the first draft of the text relating to Utility Factors for OVC-HEVs (Sub-Annex 8. Appendix5).

The test for the Ambient Temperature Correction Test has been temporarily removed from Sub-Annex 10 into a separate document, to make it easier to circulate and edit whilst developing the final text.

The document has been updated to include the results of the review into the use in the GTR of the word “recorded”. This review looked at whether “recorded” was being used to denote something that is required to be included in the test report, or something that needs to just be recorded for calculation purposes.

Other text updates are included that reflect changes in the main GTR – 26.04.14 benchmark, as well as changes agreed during AdminWG meetings in April 2014.

R.Gardner, TRL. 28th April 2014.

Further comments introduced on 28th April based on GTR 28.04.14 benchmark to:
Annex 5 Test Equipment: 4.3.1.4.7.1., 4.3.1.4.7.2,
Annex 7 Calculations: 3.2.1.3.1.2., 3.2.1.3.2.3.

Document updated to take account of comments from the AdminWG in Brussels on 29th April 2014.

Document updated to take account of comments from the AdminWG audio/web on 8th May 2014.

Document updated to take account of comments from the GTR experts (via Serge Dubuc) and other GTR updates (e.g. equation numbers added throughout for consistency of approach) 12th May 2014.

Fuel lists/details updated for emissions hydrocarbon density, dilution factors, and fuel consumption – to bring in line with 692/2008 (excluding H2NG). Comments added from AdminWG 15th May.

Updated to reflect editorial updates in the GTR (WLTP-2014-004 GTR Version 20.05.2014)

Proposals from ACEA relating to references to vehicle mass added as comments and/or text in boxes alongside existing text.

Ambient Temperature Correction Test text added back into the document in Appendix 1 to Sub-Annex 10. It had been removed for ease of drafting by a separate working group.

R.Gardner, TRL. 2nd June 2014.

~~II. Text of the global technical regulation~~

Annex XXI

Worldwide harmonized Light vehicle Test Procedures (WLTP) – EC / UNECE version

1. [Reserved for future transposition stages]

~~Purpose~~

~~This global technical regulation (gtr) aims at providing a worldwide harmonized method to determine the levels of gaseous, particulate matter, particle number, CO_2 emissions, fuel consumption, electric energy consumption and electric range from light-duty vehicles in a repeatable and reproducible manner designed to be representative of real world vehicle operation. The results will provide the basis for the regulation of these vehicles within regional type approval and certification procedures.~~

2. [Reserved for future transposition stages]

~~Scope and application~~

~~This gtr applies to vehicles of categories 1-2 and 2, both having a technically permissible maximum laden mass not exceeding 3,500 kg, and to all vehicles of category 1-1.~~

3. Definitions

The Definitions provided in this Sub-Annex …

3.1. Test equipment

3.1.1. "*Accuracy*" means the difference between a measured value and a reference value, traceable to a national standard and describes the correctness of a result. See Figure 1.

3.1.2. "*Calibration*" means the process of setting a measurement system's response so that its output agrees with a range of reference signals. Contrast with "verification".

3.1.3. "*Calibration gas*" means a gas mixture used to calibrate gas analysers.

3.1.4. "*Double dilution method*" means the process of separating a part of the diluted exhaust flow and mixing it with an appropriate amount of dilution air prior to the particulate sampling filter.

3.1.5. "*Full flow exhaust dilution system*" means the continuous dilution of the total vehicle exhaust with ambient air in a controlled manner using a constant volume sampler (CVS).

3.1.6. "*Linearization*" means the application of a range of concentrations or materials to establish a mathematical relationship between concentration and system response.

Comment [RCG1]: Purpose not needed.

Have an empty Paragraph 1. Reserved rather than deleted.

Comment [RCG2]: Scope not needed.

Have an empty Paragraph 2. Reserved rather than deleted.

Comment [RCG3]: May need a preamble to explain that the definitions in this Annex have precedent over definitions in the main Reg (Article 2 (or Para 2 of R.83)) or in the Framework Directive – if that is going to be the case.

Comment [RCG4]: Need to refine and agree the definitions that are to be included

Comment [RCG5]: Update from 250314 GTR Benchmark. Other changes made later in Annex to change "Full-flow" to "Full flow"

Deleted: *Full-flow*

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3.1.7. "*Major maintenance*" means the adjustment, repair or replacement of a component or module that could affect the accuracy of a measurement, after which calibration/validation should be performed on the parameters that could be affected.

3.1.8. "*Non-methane hydrocarbons*" (NMHC) are the total hydrocarbons (THC) minus the methane (CH_4) contribution.

3.1.9. "*Precision*" means the degree to which repeated measurements under unchanged conditions show the same results (Figure 1). In this Annex, precision requirements always refer to one standard deviation.

3.1.10. "*Reference value*" means a value traceable to a national standard. See Figure 1.

3.1.11. "*Set point*" means the target value a control system aims to reach.

3.1.12. "*Span*" means to adjust an instrument so that it gives a proper response to a calibration standard that represents between 75 per cent and 100 per cent of the maximum value in the instrument range or expected range of use.

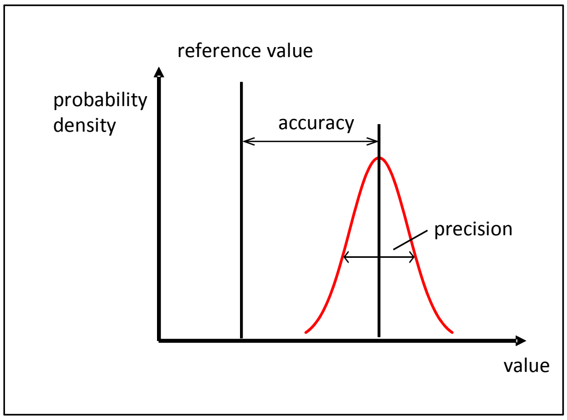
3.1.13. "*Total hydrocarbons*" (THC) means all volatile compounds measurable by a flame ionization detector (FID).

3.1.14. "*Verification*" means to evaluate whether or not a measurement system's outputs agrees with applied reference signals within one or more predetermined thresholds for acceptance.

3.1.15. "*Zero gas*" means a gas containing no analyte, which is used to set a zero response on an analyser.

Figure 1

Definition of accuracy, precision and reference value



3.2. Road and dynamometer load

3.2.1. "*Aerodynamic drag*" means the force that opposes a vehicle’s forward motion through air.

3.2.2. "*Aerodynamic stagnation point*" means the point on the surface of a vehicle where wind velocity is equal to zero.

3.2.3. "*Anemometry blockage*" means the effect on the anemometer measurement due to the presence of the vehicle where the apparent air speed is different than the vehicle speed combined with wind speed relative to the ground. By using an appropriate anemometer calibration procedure, this effect can be minimized.

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Comment [RCG6]: From Serge D: *I would rather not eliminate the term anemometry blockage at the moment, especially when using a wind tunnel in conjunction with a chassis dynamometer is still in a working stage.*

3.2.4. "*Constrained analysis*" means the vehicle's frontal area and aerodynamic drag coefficient have been independently determined and those values shall be used in the equation of motion.

3.2.5. "*Mass in running order*" means the mass of the vehicle, with its fuel tank(s) filled to at least 90 per cent of its or their capacity/capacities, including the mass of the driver and liquids, fitted with the standard equipment in accordance with the manufacturer's specifications and, when they are fitted, the mass of the bodywork, the cabin, the coupling and the spare wheel(s) as well as the tools when they are fitted.

3.2.6. "*Mass of the driver*" means a mass rated at 75 kg located at the driver's seating reference point.

3.2.7. "*Maximum vehicle load*" means in this Annex the difference between the technically permissible maximum laden mass and the sum of the mass in running order, 25 kg and the mass of the optional equipment of vehicle H.

3.2.8. "*Optional equipment*" means all the features not included in the standard equipment which are fitted to a vehicle under the responsibility of the manufacturer, and that can be ordered by the customer.

3.2.9. "*Reference atmospheric conditions (regarding road load measurements)*" means the atmospheric conditions to which these measurement results are corrected:

(a) Atmospheric pressure: p_0= 100 kPa;

(b) Atmospheric temperature: T_0= 293 K;

(c) Dry air density: ρ_0= 1.189 kg/m^3;

(d) Wind speed: 0 m/s.

3.2.10. "*Reference speed*" means the vehicle speed at which road load is determined or chassis dynamometer load is verified. Reference speeds may be continuous speed points covering the complete test cycle speed range.

3.2.11. "*Road load*" means the opposition to the movement of a vehicle. It is the total resistance if using the coastdown method or the running resistance if using the torque meter method.

3.2.12. "*Rolling resistance*" means the forces of the tyres opposing the motion of a vehicle.

3.2.13. "*Running resistance*" means the torque resisting the forward motion of a vehicle, measured by torque meters installed at the driven wheels of a vehicle.

3.2.14. "*Simulated road load*" means the road load calculated from measured coastdown data.

3.2.15. "*Speed range*" means the range of speed considered for road load determination which is between the maximum speed of the Worldwide Light-duty Test Cycle (WLTC) for the class of test vehicle and minimum speed selected by the manufacturer which shall not be greater than 20 km/h.

3.2.16. "*Stationary anemometry*" means measurement of wind speed and direction with an anemometer at a location and height above road level alongside the test road where the most representative wind conditions will be experienced.

Comment [RCG7]: ACEA (W.Coleman) proposal: "*Mass in running order*" means the mass of the vehicle, with its fuel tank(s) filled to at least 90 per cent of its or their capacity/capacities, including the mass of the driver**, of the fuel** and liquids, fitted with the standard equipment in accordance with the manufacturer's specifications and, when they are fitted, the mass of the bodywork, the cabin, the coupling and the spare wheel(s) as well as the tools ~~when they are fitted~~.

Comment [RCG8]: ACEA (W.Coleman) proposal: "Maximum vehicle load" means in this Annex the difference between the technically permissible maximum laden mass and the sum of the mass in running order, 25 kg and the mass of the optional equipment ~~of vehicle H~~.

Comment [RCG9]: From Serge D: *The various terms using the word mass are still being worked out.*

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Comment [RCG10]: Deleted (x3) by **AdminWG 010414** as it is not applicable for EC / UNECE

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Comment [RCG11]: Decimal point correction made in GTR Benchmark 04.03.2014.

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3.2.17. "*Standard equipment*" means the basic configuration of a vehicle equipped with all the features required under the regulatory acts of the Contracting Party including all features fitted without giving rise to any further specifications on configuration or equipment level.

3.2.18. "*Target road load*" means the road load to be reproduced on the chassis dynamometer.

3.2.19. "*Total resistance*" means the total force resisting movement of a vehicle, including the frictional forces in the drivetrain.

3.2.20. "*Vehicle coastdown mode*" means a mode of operation enabling an accurate and repeatable determination of total resistance and an accurate dynamometer setting.

3.2.21. "*Vehicle H*" means the vehicle within the CO_2 vehicle family with the combination of road load relevant characteristics (e.g. mass, aerodynamic drag and tyre rolling resistance) producing the highest cycle energy demand.

3.2.22. "*Vehicle L*" means the vehicle within the CO_2 vehicle family with the combination of road load relevant characteristics (e.g. mass, aerodynamic drag and tyre rolling resistance) producing the lowest cycle energy demand.

3.2.23. "*Wind correction*" means correction of the effect of wind on road load based on input of the stationary or on-board anemometry.

[Bill C. proposal for additional definitions:

16-May-14

3.2.a. 'mass of the optional equipment' means the mass of the equipment which may be fitted to the vehicle in addition to the standard equipment, in accordance with the manufacturer's specifications;

3.2.b. 'technically permissible maximum laden mass' (M) means the maximum mass allocated to a vehicle on the basis of its construction features and its design performances;

3.2.c. 'actual mass of the vehicle' means the mass in running order plus the mass of the optional equipment fitted to an individual vehicle;

3.2.d. 'test mass of the vehicle' means the sum of the actual mass of the vehicle, 25 kg and mass representative of the vehicle load;

3.2.e. 'mass representative of the vehicle load' means 15 per cent for category 1 vehicles or 28 per cent for category 2 vehicles from the maximum vehicle load.]

3.3. Pure electric vehicles and hybrid electric vehicles

3.3.1. "*All-electric range*" (AER) in the case of an off-vehicle charging hybrid electric vehicle (OVC-HEV) means the total distance travelled from the beginning of the charge-depleting test over a number of complete WLTCs to the point in time during the test when the combustion engine starts to consume fuel.

3.3.2. "*All-electric range*" (AER) in the case of a pure electric vehicle (PEV) means the total distance travelled from the beginning of the

Comment [RCG12]: ACEA (W.Coleman) **proposal:** "Standard equipment" means the basic configuration of a vehicle **which is** equipped with all the features **that are** required under the regulatory acts **[referred to in Annex IV and Annex XI to Directive 2007/46/EC]** ~~[of the Contracting Party]~~ including all features **that are** fitted without giving rise to any further specifications on configuration or equipment level.

Comment [RCG13]: **For AdminWG 150514** Confirm whether this needs to be amended or deleted.

Comment [RCG14]: ACEA (W.Coleman) **proposal:** "Vehicle H" means the **vehicle selected for testing** within the CO_2 vehicle family with the combination of road load relevant characteristics (~~e.g.~~ i.e. mass, aerodynamic drag and tyre rolling resistance) producing the highest cycle energy demand.

Comment [RCG15]: ACEA (W.Coleman) **proposal:** "Vehicle L" means the **vehicle selected for testing** within the CO_2 vehicle family with the combination of road load relevant characteristics (~~e.g.~~ i.e. mass, aerodynamic drag and tyre rolling resistance) producing the lowest cycle energy demand.

charge-depleting test over a number of WLTCs until the break-off criterion is reached.

3.3.3. "*Charge-depleting actual range*" (R_{CDA}) means the distance travelled in a series of WLTCs in charge-depleting operation condition until the rechargeable electric energy storage system (REESS) is depleted.

3.3.4. "*Charge-depleting cycle range*" (R_{CDC}) means the distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criterion, including the transition cycle where the vehicle may have operated in both depleting and sustaining modes.

3.3.5. "*Charge-depleting operation condition*" means an operating condition in which the energy stored in the REESS may fluctuate but, on average, decreases while the vehicle is driven until transition to charge-sustaining operation.

3.3.6. "*Charge-depleting break-off criterion*" is determined based on absolute net energy change.

3.3.7. "*Charge-sustaining operation condition*" means an operating condition in which the energy stored in the REESS may fluctuate but, on average, is maintained at a neutral charging balance level while the vehicle is driven.

3.3.8. "*Electric machine*" (EM) means an energy converter transforming electric energy into mechanical energy or vice versa.

3.3.9. "*Electrified vehicle*" (EV) means a vehicle using at least one electric machine for the purpose of vehicle propulsion.

3.3.10. "*Energy converter*" means the part of the powertrain converting one form of energy into a different one.

3.3.11. "*Energy storage system*" means the part of the powertrain on board a vehicle that can store chemical, electrical or mechanical energy and which can be refilled or recharged externally and/or internally.

3.3.12. "*Equivalent all-electric range*" (EAER) means that portion of the total charge-depleting actual range (R_{CDA}) attributable to the use of electricity from the REESS over the charge-depleting range test.

3.3.13. "*Highest fuel consuming mode*" means the mode with the highest fuel consumption of all driver-selectable modes.

3.3.14. "*Hybrid electric vehicle*" (HEV) means a vehicle with a powertrain containing at least one fuel consuming and one electric energy converter as well as fuel and electric energy storage systems.

3.3.15. "*Hybrid vehicle*" (HV) means a vehicle with a powertrain containing at least two different types of energy converters and two different types of energy storage systems.

3.3.16. "*Net energy change*" means the ratio of the REESS energy change divided by the cycle energy demand of the test vehicle.

3.3.17. "*Not off-vehicle charging*" (NOVC) means that the REESS cannot be charged externally. This is also known as not externally chargeable.

3.3.18. "*Not off-vehicle chargeable hybrid electric vehicle*" (NOVC-HEV) means a hybrid electric vehicle that cannot be charged externally.

3.3.19. "*Off-vehicle charging*" (OVC)" means that the REESS can be charged externally. This REESS is also known as externally-chargeable.

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Comment [RCG16]: GTR OPEN POINT: 18.05.2014: The EV group has been requested to provide a clearer definition.

Comment [RCG17]: GTR OPEN POINT: 18.05.2014: This term is not used in the GTR. Request to all experts that the definition be deleted.

Deleted: means a vehicle using at least one fuel consuming machine and one electric machine for the purpose of vehicle propulsion

Comment [RCG18]: New definition proposed by Commission, 14-Feb-14

AdminWG 010414 – it may be replaced by another new definition prepared by Iddo Riemersma.

AdminWG 290414 – it was mentioned that Christoph Albus is looking at definitions

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3.3.20. "*Off-vehicle charging hybrid electric vehicle*" (OVC-HEV) identifies a hybrid electric vehicle that can be charged externally.

3.3.21. "*Pure electric mode*" means operation by an electric machine only using electric energy from a REESS without fuel being consumed under any condition.

3.3.22. "*Pure electric vehicle*" (PEV) means a vehicle where all energy converters used for propulsion are electric machines and no other energy converter contributes to the generation of energy to be used for vehicle propulsion.

3.3.23. "*Recharged energy*"(E_{AC}) means the AC electric energy which is recharged from the grid at the mains socket.

3.3.24. "*REESS charge balance*" (RCB) means the charge balance of the REESS measured in Ah.

3.3.25. "*REESS correction criterion*" means the RCB value (Ah) which determines if and when correction of the CO_2 emissions and/or fuel consumption value in charge-sustaining (CS) operation condition is necessary.

3.4. Powertrain

3.4.1. "*Manual transmission*" means a transmission where gears are shifted by hand in conjunction with manual disengagement of a clutch.

3.5. General

3.5.1. "*Auxiliaries*" means additional equipment and/or devices not required for vehicle operation.

3.5.2. [not applicable]

3.5.3. [not applicable]

3.5.4. [not applicable]

3.5.5. [not applicable]

3.5.6. "*Cycle energy demand*" means the calculated positive energy required by the vehicle to drive the prescribed cycle.

3.5.7. "*Defeat device*" means any element of design which senses temperature, vehicle speed, engine rotational speed, drive 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:

(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; or

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

(c) Conditions are substantially included in the Type 1 test procedures.

3.5.8. "*Mode*" means a distinct driver-selectable condition which could affect emissions, and fuel and energy consumption.

3.5.9. "*Multi-mode*" means that more than one operating mode can be selected by the driver or automatically set.

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Comment [RCG19]: Delete.
These definitions are not applicable at EC/UNECE level.

Don't replace with definitions of M1, N1 etc., as they are defined in higher level documents (i.e. Consolidated Resolution on the Construction of Vehicles (R.E.3) and Annex 2 of 2007/46/EC as amended by Commission Regulation (EU) No 678/2011 of 14 July 2011)

If we delete and renumber those paragraphs below beware of x-ref implications

AdminWG 080514 – [not applicable] added

Deleted: "*Category 1 vehicle*" means a power driven vehicle with four or more wheels designed and constructed primarily for the carriage of one or more persons.

Deleted: "*Category 1-1 vehicle*" means a category 1 vehicle comprising not more than eight seating positions in addition to the driver's seating position. A category 1-1 vehicle may have standing passengers.

Deleted: "*Category 1-2 vehicle*" means a category 1 vehicle designed for the carriage of more than eight passengers, whether seated or standing, in addition to the driver.

Deleted: "*Category 2 vehicle*" means a power driven vehicle with four or more wheels designed and constructed primarily for the carriage of goods. This category shall also include:¶
(a) Tractive units;¶
(b) Chassis designed specifically to be equipped with special equipment.

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3.5.10. "*Predominant mode*" for the purposes of this Annex means a single mode that is always selected when the vehicle is switched on regardless of the operating mode selected when the vehicle was previously shut down. The predominant mode must not be able to be redefined. The switch of the predominant mode to another available mode after the vehicle being switched on shall only be possible by an intentional action of the driver.

3.5.11. "*Reference conditions (with regards to calculating mass emissions)*" means the conditions upon which gas densities are based, namely 101.325 kPa and 273.15 K.

3.5.12. "*Exhaust emissions*" means the emission of gaseous compounds, particulate matter and particle number at the tailpipe of a vehicle.

3.5.13. "*Type 1 test*" means a test used to measure a vehicle's cold start gaseous, particulate matter, particle number, CO_2 emissions, fuel consumption, electric energy consumption and electric range at ambient conditions.

3.6. PM/PN

3.6.1. "*Particle number*" (PN) means the total number of solid particles emitted from the vehicle exhaust and as specified in this Annex.

3.6.2. "*Particulate matter*" (PM) means any material collected on the filter media from diluted vehicle exhaust as specified in this Annex.

3.7. WLTC

3.7.1. "*Rated engine power*" (P_{rated}) means maximum engine power in kW as per the certification procedure based on current regional regulation. In the absence of a definition, the rated engine power shall be declared by the manufacturer according to Annex XX of this Regulation.

3.7.2. "*Maximum speed*" (v_{max}) means the maximum speed of a vehicle as declared by the manufacturer.

3.7.3. "*Rated engine speed*" means the range of rotational speed at which an engine develops maximum power.

3.7.4. "*WLTC city cycle*" means a low phase followed by a medium phase.

3.8. Procedure

3.8.1. "*Periodically regenerating system*" means an exhaust emissions control 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 during vehicle preparation cycle, it will be considered as a continuously regenerating system which does not require a special test procedure.

4. Abbreviations

4.1. General abbreviations

ATCT	Ambient Temperature Correction Test
CFV	Critical flow venturi
CFO	Critical flow orifice

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Comment [RCG20]: AdminWG 040414 – EU 136/2014 introduces x-ref (in 692/2008) to Reg 85. Therefore we should use x-ref from relevant part of updated 692/2008.

Post AdminWG 290414 – x-ref is now to Annex XX of 692/2008 (this Regulation) -as introduced by EU 136/2014.

Deleted: Regulation No. 85

Comment [RCG21]: AdminWG 290414 – In relation to max speed, need to insert in manufacturer's information document:

"4.7. Maximum vehicle design speed (in km/h) (q): ...."

Comment [RCG22]: AdminWG 010414 – EU is not a signatory to R.68 so needs to be reworded.

AdminWG 080514 – updated. Query as to whether the definition serves any purpose.

NB: a x-ref to this definition is provided in para 1.2. of Sub-Annex 1.

Deleted: defined by the Contracting Party. In the absence of a definition, the maximum speed shall be declared by the manufacturer according to Regulation No. 68.

CLD	Chemiluminescent detector
CLA	Chemiluminescent analyser
CVS	Constant volume sampler
deNO$_x$	NO$_x$ after-treatment system
ECD	Electron capture detector
ET	Evaporation tube
Extra High$_2$	WLTC extra high speed phase for Class 2 vehicles
Extra High$_3$	WLTC extra high speed phase for Class 3 vehicles
FID	Flame ionization detector
FTIR	Fourier transform infrared analyser
GC	Gas chromatograph
HEPA	High efficiency particulate air (filter)
HFID	Heated flame ionization detector
High$_2$	WLTC high speed phase for Class 2 vehicles
High$_{3-1}$	WLTC high speed phase for Class 3 vehicles with $v_{max} < 120$ km/h
High$_{3-2}$	WLTC high speed phase for Class 3 vehicles with $v_{max} \geq 120$ km/h
LoD	Limit of detection
LoQ	Limit of quantification
Low$_1$	WLTC low speed phase for Class 1 vehicles
Low$_2$	WLTC low speed phase for Class 2 vehicles
Low$_3$	WLTC low speed phase for Class 3 vehicles
Medium$_1$	WLTC medium speed phase for Class 1 vehicles
Medium$_2$	WLTC medium speed phase for Class 2 vehicles
Medium$_{3-1}$	WLTC medium speed phase for Class 3 vehicles with $v_{max} < 120$ km/h
Medium$_{3-2}$	WLTC medium speed phase for Class 3 vehicles with $v_{max} \geq 120$ km/h
LPG	Liquefied petroleum gas
NDIR	Non-dispersive infrared (analyser)
NMC	Non-methane cutter
NOVC	Not off-vehicle charging
NOVC-HEV	Not off-vehicle chargeable hybrid electric vehicle
OVC	Off-vehicle charging
PAO	Poly-alpha-olefin
PCF	Particle pre-classifier
PCRF	Particle concentration reduction factor
PDP	Positive displacement pump
Per cent FS	Per cent of full scale

Comment [RCG23]: GTR now uses capital C i.e. "Class 2"

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Comment [RCG24]: Added by TRL. GTR updated accordingly.

Comment [RCG25]: Added by TRL. GTR updated accordingly.

PM	Particulate matter
PN	Particle number
PNC	Particle number counter
PND_1	First particle number dilution device
PND_2	Second particle number dilution device
PTS	Particle transfer system
PTT	Particle transfer tube
QCL-IR	Infrared quantum cascade laser
R_{CDA}	Charge-depleting actual range
RCB	REESS charge balance
REESS	Rechargeable electric energy storage system
SSV	Subsonic venturi
USFM	Ultrasonic flow meter
VPR	Volatile particle remover
WLTC	Worldwide light-duty test cycle

4.2. Chemical symbols and abbreviations

C_1	Carbon 1 equivalent hydrocarbon
CH_4	Methane
C_2H_6	Ethane
C_2H_5OH	Ethanol
C_3H_8	Propane
CO	Carbon monoxide
CO_2	Carbon dioxide
DOP	Di-octylphthalate
THC	Total hydrocarbons (all compounds measurable by an FID)
H_2O	Water
NMHC	Non-methane hydrocarbons
NO_x	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide

5. General requirements

5.1. The vehicle and its components liable to affect the emissions of gaseous compounds, particulate matter and particle number shall be so designed, constructed and assembled as to enable the vehicle in normal use and under normal conditions of use such as humidity, rain, snow, heat, cold, sand, dirt, vibrations, wear, etc. to comply with the provisions of this Annex during its useful life.

Comment [RCG26]: Added in 250314 GTR Benchmark

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5.1.1. This shall include the security of all hoses, joints and connections used within the emission control systems.

5.2. The test vehicle shall be representative in terms of its emissions-related components and functionality of the intended production series to be covered by the approval. The manufacturer and the approval authority shall agree which vehicle test model is representative.

5.3. Vehicle testing condition

5.3.1. The types and amounts of lubricants and coolant for emissions testing shall be as specified for normal vehicle operation by the manufacturer.

5.3.2. The type of fuel for emissions testing shall be as specified in Sub-Annex 3 to this Annex.

5.3.3. All emissions controlling systems shall be in working order.

5.3.4. The use of any defeat device is prohibited.

5.3.5. The engine shall be designed to avoid crankcase emissions.

5.3.6. The tyres used for emissions testing shall be as defined in paragraph 1.2.4.5. of Sub-Annex 6 to this Annex.

5.4. Petrol tank inlet orifices

5.4.1. Subject to paragraph 5.4.2. below, the inlet orifice of the petrol or ethanol tank shall be so designed as to prevent the tank from being filled from a fuel pump delivery nozzle which has an external diameter of 23.6 mm or greater.

5.4.2. Paragraph 5.4.1. shall not apply to a vehicle in respect of which both of the following conditions are satisfied:

(a) The vehicle is so designed and constructed that no device designed to control the emission of gaseous and particulate compounds shall be adversely affected by leaded petrol; and

(b) The vehicle is conspicuously, legibly and indelibly marked with the symbol for unleaded petrol, specified in ISO 2575:2010 "Road vehicles -- Symbols for controls, indicators and tell-tales", in a position immediately visible to a person filling the petrol tank. Additional markings are permitted.

5.5. Provisions for electronic system security

5.5.1. Any vehicle with an emission control computer shall include features to deter modification, except as authorised by the manufacturer. The manufacturer shall authorise modifications if these modifications are necessary for the diagnosis, servicing, inspection, retrofitting or repair of the vehicle. Any reprogrammable computer codes or operating parameters shall be resistant to tampering and afford a level of protection at least as good as the provisions in ISO 15031-7 (March 15, 2001). 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.

5.5.2. 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) enclosures).

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Comment [RCG27]: May want to change this to refer directly to the relevant annex of 692/2008 (i.e. Annex IX). Sub-Annex 3 will just be providing this sign-posting to Annex IX anyway, so do we want to 'cut out the middle-man'?

AdminWG 010414 – best to have as few external x-refs as possible (to aid future updates) therefore leave this as Sub-Annex 3 (which will have the 'exit' to Annex IX).

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5.5.3. Manufacturers may seek approval from the approval authority for an exemption to one of these requirements for those vehicles which are unlikely to require protection. The criteria that the approval authority 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.

5.5.4. Manufacturers using programmable computer code systems shall deter unauthorised 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 approval authority.

5.6. CO_2 vehicle family

5.6.1. Vehicles identical with respect to the following vehicle/powertrain/transmission characteristics shall be considered to be part of the same CO_2 vehicle family:

(a) Type of internal combustion engine: fuel type, combustion type, engine displacement, full-load characteristics, engine technology, and charging system shall be identical, but also other engine subsystems or characteristics that have a non-negligible influence on CO_2 under WLTP conditions;

(b) Operation strategy of all CO_2-influencing components within the powertrain;

(c) Transmission type (e.g. manual, automatic, CVT);

(d) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the transmission ratios of the most commonly installed transmission type is within 8 per cent;

(e) Number of powered axles;

(f) [RESERVED: family criteria for EVs].

6. Performance requirements

6.1. Limit values

Limit values for emissions shall be those specified in Annex I of Regulation (EC) No 715/2007.

6.2. Testing

Testing shall be performed according to:

(a) The WLTCs as described in Sub-Annex 1;

(b) The gear selection and shift point determination as described in Sub-Annex 2;

(c) The appropriate fuel as described in Sub-Annex 3;

(d) The road and dynamometer load as described in Sub-Annex 4;

(e) The test equipment as described in Sub-Annex 5;

(f) The test procedures as described in Sub-Annexes 6, 8 and 10;

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Comment [RCG28]: AdminWG 010414 – UTAC commented that 'emissions families' should also be mentioned here.

AdminWG 290414 – it was agreed that this should be discussed as a GTR issue in Geneva rather than as an EU in Brussels

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Comment [RCG29]: Update from 20-05-14 GTR

Comment [RCG30]: 280514 – query for S.Dubuc relating to the text update included in 20.05.14 GTR.

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Comment [RCG31]: Need to amend to make EU relevant/specific.

AdminWG 080514 – agreed to just provide a x-ref to the limits in EU No 715/2007.

Deleted: When implementing the test procedure contained in this gtr as part of their national legislation, Contracting Parties to the 1998 Agreement are encouraged to use limit values which represent at least the same level of severity as their existing regulations; pending the development of harmonized limit values, by the Executive Committee (AC.3) of the 1998 Agreement, for inclusion in the gtr at a later date.

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Comment [RCG32]: Added new Annex 10 which includes the Normalisation Procedures relating to the regional temperature corrections and possibly test cycle flexibilities

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(g) The methods of calculation as described in Sub-Annexes 7 and 8.

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Comment [RCG33]: Sub-Annex 9 covering 'Determination of System Equivalence" which is currently an empty annex will remain reserved.

This is on the Phase 1b action list

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Submitted by the European Commission

Informal document GRPE-69-16
69th GRPE, 5 – 6 June 2014
Agenda item 3a

Sub-Annex 1

Worldwide light-duty test cycles (WLTC)

1. General requirements

1.1. The cycle to be driven shall be dependent on the test vehicle's rated power to unladen mass ratio, W/kg, and its maximum velocity, v_{max}.

1.2. v_{max} is the maximum speed of a vehicle as defined in paragraph 3.7.2. of this Annex) and not that which may be artificially restricted.

2. Vehicle classifications

2.1. Class 1 vehicles have a power to unladen mass ratio P_{mr} ≤ 22 W/kg.

2.2. Class 2 vehicles have a power to unladen mass ratio > 22 but ≤ 34 W/kg.

2.3. Class 3 vehicles have a power to unladen mass ratio > 34 W/kg.

2.3.1. All vehicles tested according to Sub-Annex 8 shall be considered to be Class 3 vehicles.

3. Test cycles

3.1. Class 1 vehicles

3.1.1. A complete cycle for Class 1 vehicles shall consist of a low phase (Low_1), a medium phase ($Medium_1$) and an additional low phase (Low_1).

3.1.2. The Low_1 phase is described in Figure A1/1 and Table A1/1.

3.1.3. The $Medium_1$ phase is described in Figure A1/2 and Table A1/2.

3.2. Class 2 vehicles

3.2.1. A complete cycle for Class 2 vehicles shall consist of a low phase (Low_2), a medium phase ($Medium_2$), a high phase ($High_2$) and an extra high phase (Extra $High_2$).

3.2.2. The Low_2 phase is described in Figure A1/3 and Table A1/3.

3.2.3. The $Medium_2$ phase is described in Figure A1/4 and Table A1/4.

3.2.4. The $High_2$ phase is described in Figure A1/5 and Table A1/5.

3.2.5. The Extra $High_2$ phase is described in Figure A1/6 and Table A1/6.

3.3. Class 3 vehicles

Class 3 vehicles are divided into 2 subclasses according to their maximum speed, v_{max}.

3.3.1. Class 3a vehicles with v_{max} < 120 km/h

3.3.1.1. A complete cycle shall consist of a low phase (Low_3), a medium phase ($Medium_{3-1}$), a high phase ($High_{3-1}$) and an extra high phase (Extra $High_3$).

3.3.1.2. The Low_3 phase is described in Figure A1/7 and Table A1/7.

3.3.1.3. The $Medium_{3-1}$ phase is described in Figure A1/8 and Table A1/8.

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Comment [RCG34]: AdminWG 010414 – Delete as only applicable for Japan. Not an option at EC / UNECE level

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3.2.6. At the option of the Contracting Party, the Extra $High_2$ phase may be excluded.

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3.3.1.4. The $High_{3-1}$ phase is described in Figure A1/10 and Table A1/10.

3.3.1.5. The Extra $High_3$ phase is described in Figure A1/12 and Table A1/12.

3.3.2. Class 3b vehicles with $v_{max} \geq 120$ km/h

3.3.2.1. A complete cycle shall consist of a low phase (Low_3) phase, a medium phase ($Medium_{3-2}$), a high phase ($High_{3-2}$) and an extra high phase (Extra $High_3$).

3.3.2.2. The Low_3 phase is described in Figure A1/7 and Table A1/7.

3.3.2.3. The $Medium_{3-2}$ phase is described in Figure A1/9 and Table A1/9.

3.3.2.4. The $High_{3-2}$ phase is described in Figure A1/11 and Table A1/11.

3.3.2.5. The Extra $High_3$ phase is described in Figure A1/12 and Table A1/12.

3.4. Duration of all phases

3.4.1. All low speed phases last 589 seconds (s).

3.4.2. All medium speed phases last 433 seconds (s).

3.4.3. All high speed phases last 455 seconds (s).

3.4.4. All extra high speed phases last 323 seconds (s).

3.5 WLTC city cycles

OVC-HEVs and PEVs shall be tested using the WLTC and WLTC city cycles (see Sub-Annex 8) for Class 3a and Class 3b vehicles.

The WLTC city cycle consists of the low and medium speed phases only.

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3.3.1.6. At the option of the Contracting Party, the Extra $High_3$ phase may be excluded

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4. WLTC Class 1 vehicles

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Figure A1/1

WLTC, Class 1 vehicles, phase Low_1

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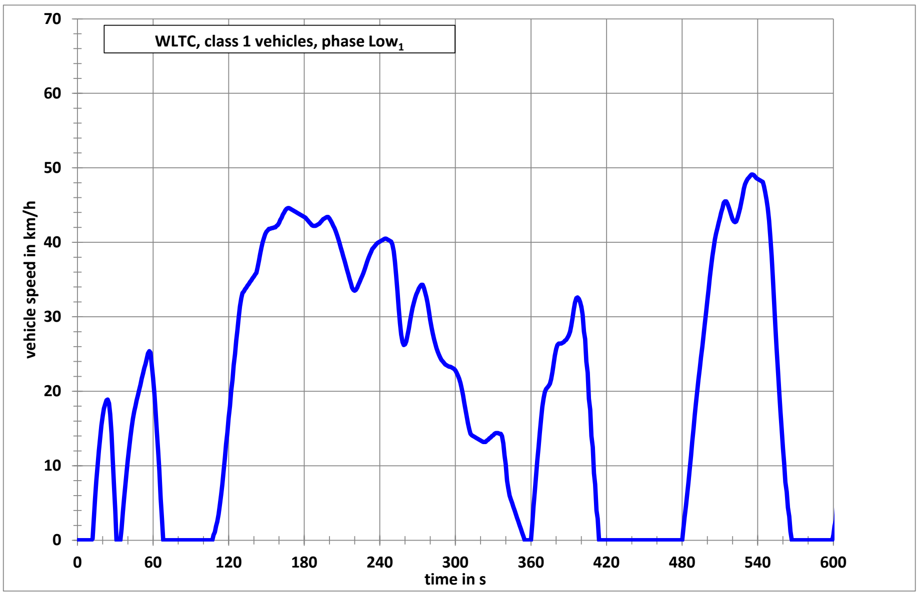

Figure A1/2

WLTC, Class 1 vehicles, phase $Medium_1$

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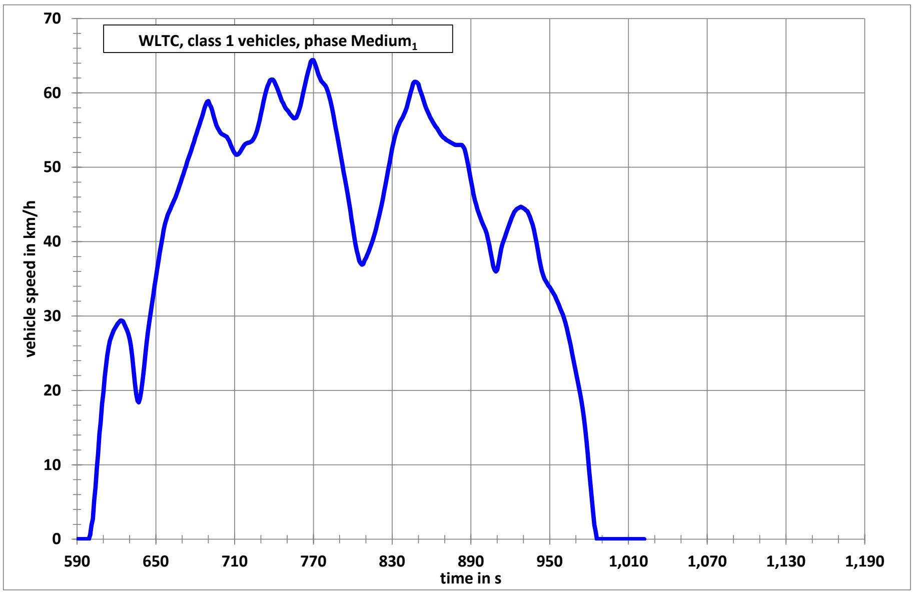

Table A1/1

WLTC, Class 1 vehicles, phase Low$_1$

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
0	0.0	47	18.8	94	0.0	141	35.7
1	0.0	48	19.5	95	0.0	142	35.9
2	0.0	49	20.2	96	0.0	143	36.6
3	0.0	50	20.9	97	0.0	144	37.5
4	0.0	51	21.7	98	0.0	145	38.4
5	0.0	52	22.4	99	0.0	146	39.3
6	0.0	53	23.1	100	0.0	147	40.0
7	0.0	54	23.7	101	0.0	148	40.6
8	0.0	55	24.4	102	0.0	149	41.1
9	0.0	56	25.1	103	0.0	150	41.4
10	0.0	57	25.4	104	0.0	151	41.6
11	0.0	58	25.2	105	0.0	152	41.8
12	0.2	59	23.4	106	0.0	153	41.8
13	3.1	60	21.8	107	0.0	154	41.9
14	5.7	61	19.7	108	0.7	155	41.9
15	8.0	62	17.3	109	1.1	156	42.0
16	10.1	63	14.7	110	1.9	157	42.0
17	12.0	64	12.0	111	2.5	158	42.2
18	13.8	65	9.4	112	3.5	159	42.3
19	15.4	66	5.6	113	4.7	160	42.6
20	16.7	67	3.1	114	6.1	161	43.0
21	17.7	68	0.0	115	7.5	162	43.3
22	18.3	69	0.0	116	9.4	163	43.7
23	18.8	70	0.0	117	11.0	164	44.0

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
24	18.9	71	0.0	118	12.9	165	44.3
25	18.4	72	0.0	119	14.5	166	44.5
26	16.9	73	0.0	120	16.4	167	44.6
27	14.3	74	0.0	121	18.0	168	44.6
28	10.8	75	0.0	122	20.0	169	44.5
29	7.1	76	0.0	123	21.5	170	44.4
30	4.0	77	0.0	124	23.5	171	44.3
31	0.0	78	0.0	125	25.0	172	44.2
32	0.0	79	0.0	126	26.8	173	44.1
33	0.0	80	0.0	127	28.2	174	44.0
34	0.0	81	0.0	128	30.0	175	43.9
35	1.5	82	0.0	129	31.4	176	43.8
36	3.8	83	0.0	130	32.5	177	43.7
37	5.6	84	0.0	131	33.2	178	43.6
38	7.5	85	0.0	132	33.4	179	43.5
39	9.2	86	0.0	133	33.7	180	43.4
40	10.8	87	0.0	134	33.9	181	43.3
41	12.4	88	0.0	135	34.2	182	43.1
42	13.8	89	0.0	136	34.4	183	42.9
43	15.2	90	0.0	137	34.7	184	42.7
44	16.3	91	0.0	138	34.9	185	42.5
45	17.3	92	0.0	139	35.2	186	42.3
46	18.0	93	0.0	140	35.4	187	42.2
188	42.2	237	39.7	286	25.3	335	14.3
189	42.2	238	39.9	287	24.9	336	14.3
190	42.3	239	40.0	288	24.5	337	14.0
191	42.4	240	40.1	289	24.2	338	13.0
192	42.5	241	40.2	290	24.0	339	11.4
193	42.7	242	40.3	291	23.8	340	10.2
194	42.9	243	40.4	292	23.6	341	8.0
195	43.1	244	40.5	293	23.5	342	7.0
196	43.2	245	40.5	294	23.4	343	6.0
197	43.3	246	40.4	295	23.3	344	5.5
198	43.4	247	40.3	296	23.3	345	5.0
199	43.4	248	40.2	297	23.2	346	4.5
200	43.2	249	40.1	298	23.1	347	4.0
201	42.9	250	39.7	299	23.0	348	3.5
202	42.6	251	38.8	300	22.8	349	3.0
203	42.2	252	37.4	301	22.5	350	2.5
204	41.9	253	35.6	302	22.1	351	2.0
205	41.5	254	33.4	303	21.7	352	1.5
206	41.0	255	31.2	304	21.1	353	1.0
207	40.5	256	29.1	305	20.4	354	0.5
208	39.9	257	27.6	306	19.5	355	0.0
209	39.3	258	26.6	307	18.5	356	0.0
210	38.7	259	26.2	308	17.6	357	0.0
211	38.1	260	26.3	309	16.6	358	0.0
212	37.5	261	26.7	310	15.7	359	0.0

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
213	36.9	262	27.5	311	14.9	360	0.0
214	36.3	263	28.4	312	14.3	361	2.2
215	35.7	264	29.4	313	14.1	362	4.5
216	35.1	265	30.4	314	14.0	363	6.6
217	34.5	266	31.2	315	13.9	364	8.6
218	33.9	267	31.9	316	13.8	365	10.6
219	33.6	268	32.5	317	13.7	366	12.5
220	33.5	269	33.0	318	13.6	367	14.4
221	33.6	270	33.4	319	13.5	368	16.3
222	33.9	271	33.8	320	13.4	369	17.9
223	34.3	272	34.1	321	13.3	370	19.1
224	34.7	273	34.3	322	13.2	371	19.9
225	35.1	274	34.3	323	13.2	372	20.3
226	35.5	275	33.9	324	13.2	373	20.5
227	35.9	276	33.3	325	13.4	374	20.7
228	36.4	277	32.6	326	13.5	375	21.0
229	36.9	278	31.8	327	13.7	376	21.6
230	37.4	279	30.7	328	13.8	377	22.6
231	37.9	280	29.6	329	14.0	378	23.7
232	38.3	281	28.6	330	14.1	379	24.8
233	38.7	282	27.8	331	14.3	380	25.7
234	39.1	283	27.0	332	14.4	381	26.2
235	39.3	284	26.4	333	14.4	382	26.4
236	39.5	285	25.8	334	14.4	383	26.4
384	26.4	433	0.0	482	3.1	531	48.2
385	26.5	434	0.0	483	4.6	532	48.5
386	26.6	435	0.0	484	6.1	533	48.7
387	26.8	436	0.0	485	7.8	534	48.9
388	26.9	437	0.0	486	9.5	535	49.1
389	27.2	438	0.0	487	11.3	536	49.1
390	27.5	439	0.0	488	13.2	537	49.0
391	28.0	440	0.0	489	15.0	538	48.8
392	28.8	441	0.0	490	16.8	539	48.6
393	29.9	442	0.0	491	18.4	540	48.5
394	31.0	443	0.0	492	20.1	541	48.4
395	31.9	444	0.0	493	21.6	542	48.3
396	32.5	445	0.0	494	23.1	543	48.2
397	32.6	446	0.0	495	24.6	544	48.1
398	32.4	447	0.0	496	26.0	545	47.5
399	32.0	448	0.0	497	27.5	546	46.7
400	31.3	449	0.0	498	29.0	547	45.7
401	30.3	450	0.0	499	30.6	548	44.6
402	28.0	451	0.0	500	32.1	549	42.9
403	27.0	452	0.0	501	33.7	550	40.8
404	24.0	453	0.0	502	35.3	551	38.2
405	22.5	454	0.0	503	36.8	552	35.3
406	19.0	455	0.0	504	38.1	553	31.8
407	17.5	456	0.0	505	39.3	554	28.7
408	14.0	457	0.0	506	40.4	555	25.8

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
409	12.5	458	0.0	507	41.2	556	22.9
410	9.0	459	0.0	508	41.9	557	20.2
411	7.5	460	0.0	509	42.6	558	17.3
412	4.0	461	0.0	510	43.3	559	15.0
413	2.9	462	0.0	511	44.0	560	12.3
414	0.0	463	0.0	512	44.6	561	10.3
415	0.0	464	0.0	513	45.3	562	7.8
416	0.0	465	0.0	514	45.5	563	6.5
417	0.0	466	0.0	515	45.5	564	4.4
418	0.0	467	0.0	516	45.2	565	3.2
419	0.0	468	0.0	517	44.7	566	1.2
420	0.0	469	0.0	518	44.2	567	0.0
421	0.0	470	0.0	519	43.6	568	0.0
422	0.0	471	0.0	520	43.1	569	0.0
423	0.0	472	0.0	521	42.8	570	0.0
424	0.0	473	0.0	522	42.7	571	0.0
425	0.0	474	0.0	523	42.8	572	0.0
426	0.0	475	0.0	524	43.3	573	0.0
427	0.0	476	0.0	525	43.9	574	0.0
428	0.0	477	0.0	526	44.6	575	0.0
429	0.0	478	0.0	527	45.4	576	0.0
430	0.0	479	0.0	528	46.3	577	0.0
431	0.0	480	0.0	529	47.2	578	0.0
432	0.0	481	1.6	530	47.8	579	0.0
580	0.0						
581	0.0						
582	0.0						
583	0.0						
584	0.0						
585	0.0						
586	0.0						
587	0.0						
588	0.0						
589	0.0						

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*

Table A1/2

WLTC, Class 1 vehicles, phase Medium[1]

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
590	0.0	637	18.4	684	56.2	731	57.9
591	0.0	638	19.0	685	56.7	732	58.8
592	0.0	639	20.1	686	57.3	733	59.6
593	0.0	640	21.5	687	57.9	734	60.3
594	0.0	641	23.1	688	58.4	735	60.9
595	0.0	642	24.9	689	58.8	736	61.3
596	0.0	643	26.4	690	58.9	737	61.7
597	0.0	644	27.9	691	58.4	738	61.8
598	0.0	645	29.2	692	58.1	739	61.8
599	0.0	646	30.4	693	57.6	740	61.6
600	0.6	647	31.6	694	56.9	741	61.2
601	1.9	648	32.8	695	56.3	742	60.8
602	2.7	649	34.0	696	55.7	743	60.4
603	5.2	650	35.1	697	55.3	744	59.9
604	7.0	651	36.3	698	55.0	745	59.4
605	9.6	652	37.4	699	54.7	746	58.9
606	11.4	653	38.6	700	54.5	747	58.6
607	14.1	654	39.6	701	54.4	748	58.2
608	15.8	655	40.6	702	54.3	749	57.9
609	18.2	656	41.6	703	54.2	750	57.7
610	19.7	657	42.4	704	54.1	751	57.5

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
611	21.8	658	43.0	705	53.8	752	57.2
612	23.2	659	43.6	706	53.5	753	57.0
613	24.7	660	44.0	707	53.0	754	56.8
614	25.8	661	44.4	708	52.6	755	56.6
615	26.7	662	44.8	709	52.2	756	56.6
616	27.2	663	45.2	710	51.9	757	56.7
617	27.7	664	45.6	711	51.7	758	57.1
618	28.1	665	46.0	712	51.7	759	57.6
619	28.4	666	46.5	713	51.8	760	58.2
620	28.7	667	47.0	714	52.0	761	59.0
621	29.0	668	47.5	715	52.3	762	59.8
622	29.2	669	48.0	716	52.6	763	60.6
623	29.4	670	48.6	717	52.9	764	61.4
624	29.4	671	49.1	718	53.1	765	62.2
625	29.3	672	49.7	719	53.2	766	62.9
626	28.9	673	50.2	720	53.3	767	63.5
627	28.5	674	50.8	721	53.3	768	64.2
628	28.1	675	51.3	722	53.4	769	64.4
629	27.6	676	51.8	723	53.5	770	64.4
630	26.9	677	52.3	724	53.7	771	64.0
631	26.0	678	52.9	725	54.0	772	63.5
632	24.6	679	53.4	726	54.4	773	62.9
633	22.8	680	54.0	727	54.9	774	62.4
634	21.0	681	54.5	728	55.6	775	62.0
635	19.5	682	55.1	729	56.3	776	61.6
636	18.6	683	55.6	730	57.1	777	61.4
778	61.2	827	49.7	876	53.2	925	44.4
779	61.0	828	50.6	877	53.1	926	44.5
780	60.7	829	51.6	878	53.0	927	44.6
781	60.2	830	52.5	879	53.0	928	44.7
782	59.6	831	53.3	880	53.0	929	44.6
783	58.9	832	54.1	881	53.0	930	44.5
784	58.1	833	54.7	882	53.0	931	44.4
785	57.2	834	55.3	883	53.0	932	44.2
786	56.3	835	55.7	884	52.8	933	44.1
787	55.3	836	56.1	885	52.5	934	43.7
788	54.4	837	56.4	886	51.9	935	43.3
789	53.4	838	56.7	887	51.1	936	42.8
790	52.4	839	57.1	888	50.2	937	42.3
791	51.4	840	57.5	889	49.2	938	41.6
792	50.4	841	58.0	890	48.2	939	40.7
793	49.4	842	58.7	891	47.3	940	39.8
794	48.5	843	59.3	892	46.4	941	38.8
795	47.5	844	60.0	893	45.6	942	37.8
796	46.5	845	60.6	894	45.0	943	36.9
797	45.4	846	61.3	895	44.3	944	36.1
798	44.3	847	61.5	896	43.8	945	35.5
799	43.1	848	61.5	897	43.3	946	35.0

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
800	42.0	849	61.4	898	42.8	947	34.7
801	40.8	850	61.2	899	42.4	948	34.4
802	39.7	851	60.5	900	42.0	949	34.1
803	38.8	852	60.0	901	41.6	950	33.9
804	38.1	853	59.5	902	41.1	951	33.6
805	37.4	854	58.9	903	40.3	952	33.3
806	37.1	855	58.4	904	39.5	953	33.0
807	36.9	856	57.9	905	38.6	954	32.7
808	37.0	857	57.5	906	37.7	955	32.3
809	37.5	858	57.1	907	36.7	956	31.9
810	37.8	859	56.7	908	36.2	957	31.5
811	38.2	860	56.4	909	36.0	958	31.0
812	38.6	861	56.1	910	36.2	959	30.6
813	39.1	862	55.8	911	37.0	960	30.2
814	39.6	863	55.5	912	38.0	961	29.7
815	40.1	864	55.3	913	39.0	962	29.1
816	40.7	865	55.0	914	39.7	963	28.4
817	41.3	866	54.7	915	40.2	964	27.6
818	41.9	867	54.4	916	40.7	965	26.8
819	42.7	868	54.2	917	41.2	966	26.0
820	43.4	869	54.0	918	41.7	967	25.1
821	44.2	870	53.9	919	42.2	968	24.2
822	45.0	871	53.7	920	42.7	969	23.3
823	45.9	872	53.6	921	43.2	970	22.4
824	46.8	873	53.5	922	43.6	971	21.5
825	47.7	874	53.4	923	44.0	972	20.6
826	48.7	875	53.3	924	44.2	973	19.7
974	18.8						
975	17.7						
976	16.4						
977	14.9						
978	13.2						
979	11.3						
980	9.4						
981	7.5						
982	5.6						
983	3.7						
984	1.9						
985	1.0						
986	0.0						
987	0.0						
988	0.0						
989	0.0						
990	0.0						
991	0.0						
992	0.0						
993	0.0						
994	0.0						
995	0.0						

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
996	0.0						
997	0.0						
998	0.0						
999	0.0						
1000	0.0						
1001	0.0						
1002	0.0						
1003	0.0						
1004	0.0						
1005	0.0						
1006	0.0						
1007	0.0						
1008	0.0						
1009	0.0						
1010	0.0						
1011	0.0						
1012	0.0						
1013	0.0						
1014	0.0						
1015	0.0						
1016	0.0						
1017	0.0						
1018	0.0						
1019	0.0						
1020	0.0						
1021	0.0						
1022	0.0						

5. WLTC for Class 2 vehicles

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Figure A1/3

WLTC, Class 2 vehicles, phase Low_2

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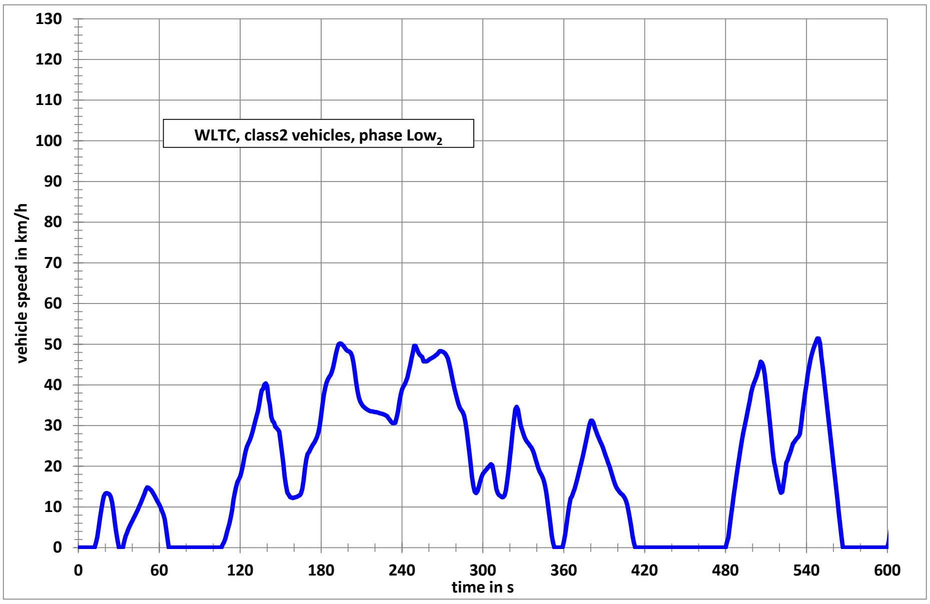

Figure A1/4

WLTC, Class 2 vehicles, phase Medium$_2$

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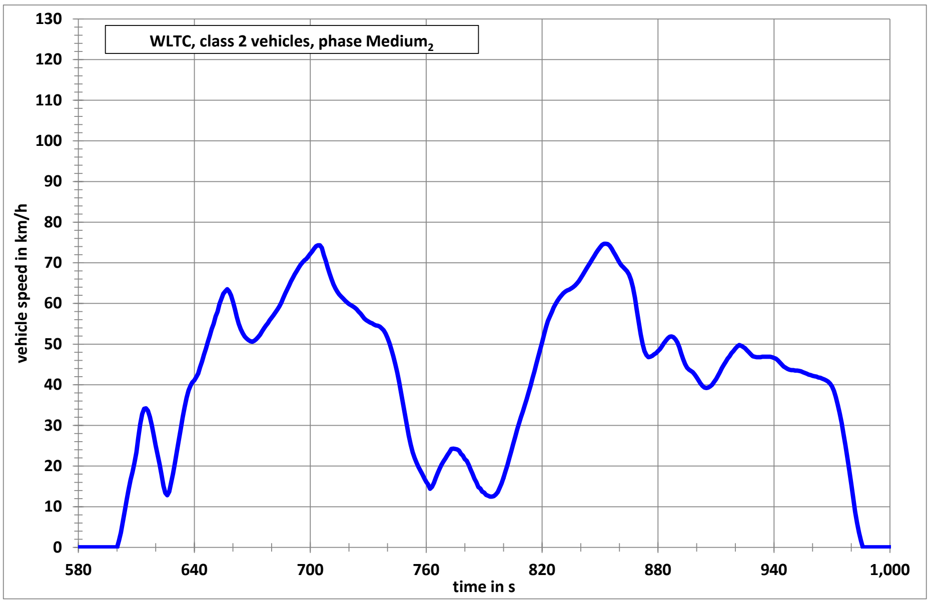

Figure A1/5

WLTC, Class 2 vehicles, phase High$_2$

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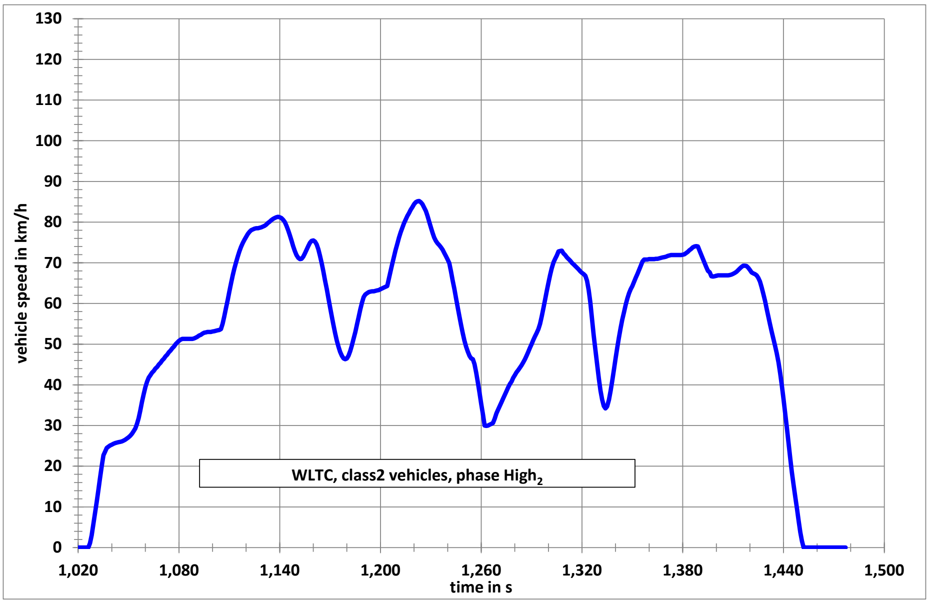

Figure A1/6
WLTC, Class 2 vehicles, phase Extra High2

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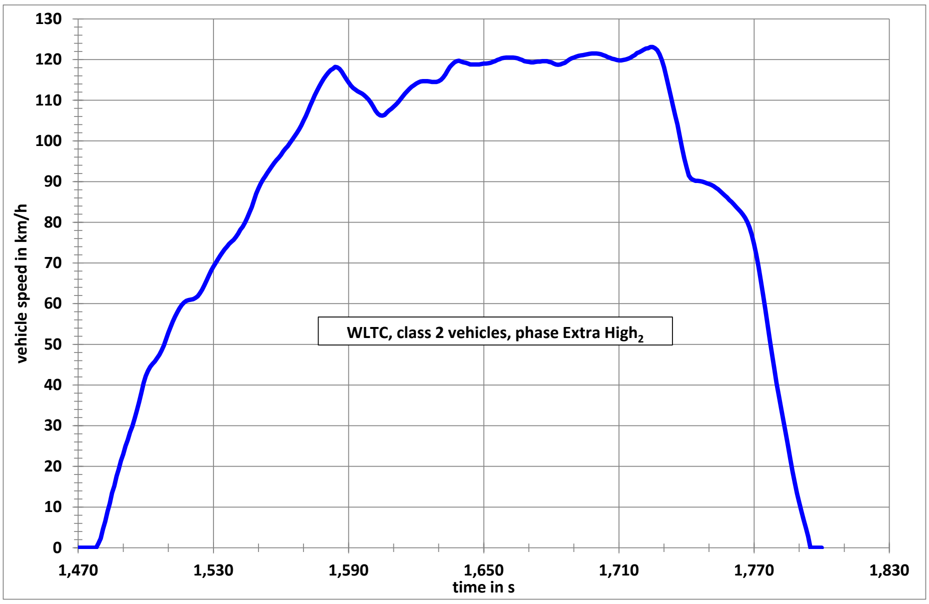

Table A1/3
WLTC, Class 2 vehicles, phase Low2

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
0	0.0	47	11.6	94	0.0	141	36.8
1	0.0	48	12.4	95	0.0	142	35.1
2	0.0	49	13.2	96	0.0	143	32.2
3	0.0	50	14.2	97	0.0	144	31.1
4	0.0	51	14.8	98	0.0	145	30.8
5	0.0	52	14.7	99	0.0	146	29.7
6	0.0	53	14.4	100	0.0	147	29.4
7	0.0	54	14.1	101	0.0	148	29.0
8	0.0	55	13.6	102	0.0	149	28.5
9	0.0	56	13.0	103	0.0	150	26.0
10	0.0	57	12.4	104	0.0	151	23.4
11	0.0	58	11.8	105	0.0	152	20.7
12	0.0	59	11.2	106	0.0	153	17.4
13	1.2	60	10.6	107	0.8	154	15.2
14	2.6	61	9.9	108	1.4	155	13.5
15	4.9	62	9.0	109	2.3	156	13.0
16	7.3	63	8.2	110	3.5	157	12.4
17	9.4	64	7.0	111	4.7	158	12.3
18	11.4	65	4.8	112	5.9	159	12.2
19	12.7	66	2.3	113	7.4	160	12.3
20	13.3	67	0.0	114	9.2	161	12.4
21	13.4	68	0.0	115	11.7	162	12.5
22	13.3	69	0.0	116	13.5	163	12.7
23	13.1	70	0.0	117	15.0	164	12.8
24	12.5	71	0.0	118	16.2	165	13.2
25	11.1	72	0.0	119	16.8	166	14.3
26	8.9	73	0.0	120	17.5	167	16.5
27	6.2	74	0.0	121	18.8	168	19.4
28	3.8	75	0.0	122	20.3	169	21.7
29	1.8	76	0.0	123	22.0	170	23.1
30	0.0	77	0.0	124	23.6	171	23.5
31	0.0	78	0.0	125	24.8	172	24.2
32	0.0	79	0.0	126	25.6	173	24.8
33	0.0	80	0.0	127	26.3	174	25.4
34	1.5	81	0.0	128	27.2	175	25.8
35	2.8	82	0.0	129	28.3	176	26.5
36	3.6	83	0.0	130	29.6	177	27.2
37	4.5	84	0.0	131	30.9	178	28.3
38	5.3	85	0.0	132	32.2	179	29.9
39	6.0	86	0.0	133	33.4	180	32.4
40	6.6	87	0.0	134	35.1	181	35.1
41	7.3	88	0.0	135	37.2	182	37.5
42	7.9	89	0.0	136	38.7	183	39.2
43	8.6	90	0.0	137	39.0	184	40.5
44	9.3	91	0.0	138	40.1	185	41.4
45	10	92	0.0	139	40.4	186	42.0
46	10.8	93	0.0	140	39.7	187	42.5
188	43.2	237	33.5	286	32.5	335	25.0
189	44.4	238	35.8	287	30.9	336	24.6

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
190	45.9	239	37.6	288	28.6	337	23.9
191	47.6	240	38.8	289	25.9	338	23.0
192	49.0	241	39.6	290	23.1	339	21.8
193	50.0	242	40.1	291	20.1	340	20.7
194	50.2	243	40.9	292	17.3	341	19.6
195	50.1	244	41.8	293	15.1	342	18.7
196	49.8	245	43.3	294	13.7	343	18.1
197	49.4	246	44.7	295	13.4	344	17.5
198	48.9	247	46.4	296	13.9	345	16.7
199	48.5	248	47.9	297	15.0	346	15.4
200	48.3	249	49.6	298	16.3	347	13.6
201	48.2	250	49.6	299	17.4	348	11.2
202	47.9	251	48.8	300	18.2	349	8.6
203	47.1	252	48.0	301	18.6	350	6.0
204	45.5	253	47.5	302	19.0	351	3.1
205	43.2	254	47.1	303	19.4	352	1.2
206	40.6	255	46.9	304	19.8	353	0.0
207	38.5	256	45.8	305	20.1	354	0.0
208	36.9	257	45.8	306	20.5	355	0.0
209	35.9	258	45.8	307	20.2	356	0.0
210	35.3	259	45.9	308	18.6	357	0.0
211	34.8	260	46.2	309	16.5	358	0.0
212	34.5	261	46.4	310	14.4	359	0.0
213	34.2	262	46.6	311	13.4	360	1.4
214	34.0	263	46.8	312	12.9	361	3.2
215	33.8	264	47.0	313	12.7	362	5.6
216	33.6	265	47.3	314	12.4	363	8.1
217	33.5	266	47.5	315	12.4	364	10.3
218	33.5	267	47.9	316	12.8	365	12.1
219	33.4	268	48.3	317	14.1	366	12.6
220	33.3	269	48.3	318	16.2	367	13.6
221	33.3	270	48.2	319	18.8	368	14.5
222	33.2	271	48.0	320	21.9	369	15.6
223	33.1	272	47.7	321	25.0	370	16.8
224	33.0	273	47.2	322	28.4	371	18.2
225	32.9	274	46.5	323	31.3	372	19.6
226	32.8	275	45.2	324	34.0	373	20.9
227	32.7	276	43.7	325	34.6	374	22.3
228	32.5	277	42.0	326	33.9	375	23.8
229	32.3	278	40.4	327	31.9	376	25.4
230	31.8	279	39.0	328	30.0	377	27.0
231	31.4	280	37.7	329	29.0	378	28.6
232	30.9	281	36.4	330	27.9	379	30.2
233	30.6	282	35.2	331	27.1	380	31.2
234	30.6	283	34.3	332	26.4	381	31.2
235	30.7	284	33.8	333	25.9	382	30.7
236	32.0	285	33.3	334	25.5	383	29.5
384	28.6	433	0.0	482	2.5	531	26.0

Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
385	27.7	434	0.0	483	5.2	532	26.5
386	26.9	435	0.0	484	7.9	533	26.9
387	26.1	436	0.0	485	10.3	534	27.3
388	25.4	437	0.0	486	12.7	535	27.9
389	24.6	438	0.0	487	15.0	536	30.3
390	23.6	439	0.0	488	17.4	537	33.2
391	22.6	440	0.0	489	19.7	538	35.4
392	21.7	441	0.0	490	21.9	539	38.0
393	20.7	442	0.0	491	24.1	540	40.1
394	19.8	443	0.0	492	26.2	541	42.7
395	18.8	444	0.0	493	28.1	542	44.5
396	17.7	445	0.0	494	29.7	543	46.3
397	16.6	446	0.0	495	31.3	544	47.6
398	15.6	447	0.0	496	33.0	545	48.8
399	14.8	448	0.0	497	34.7	546	49.7
400	14.3	449	0.0	498	36.3	547	50.6
401	13.8	450	0.0	499	38.1	548	51.4
402	13.4	451	0.0	500	39.4	549	51.4
403	13.1	452	0.0	501	40.4	550	50.2
404	12.8	453	0.0	502	41.2	551	47.1
405	12.3	454	0.0	503	42.1	552	44.5
406	11.6	455	0.0	504	43.2	553	41.5
407	10.5	456	0.0	505	44.3	554	38.5
408	9.0	457	0.0	506	45.7	555	35.5
409	7.2	458	0.0	507	45.4	556	32.5
410	5.2	459	0.0	508	44.5	557	29.5
411	2.9	460	0.0	509	42.5	558	26.5
412	1.2	461	0.0	510	39.5	559	23.5
413	0.0	462	0.0	511	36.5	560	20.4
414	0.0	463	0.0	512	33.5	561	17.5
415	0.0	464	0.0	513	30.4	562	14.5
416	0.0	465	0.0	514	27.0	563	11.5
417	0.0	466	0.0	515	23.6	564	8.5
418	0.0	467	0.0	516	21.0	565	5.6
419	0.0	468	0.0	517	19.5	566	2.6
420	0.0	469	0.0	518	17.6	567	0.0
421	0.0	470	0.0	519	16.1	568	0.0
422	0.0	471	0.0	520	14.5	569	0.0
423	0.0	472	0.0	521	13.5	570	0.0
424	0.0	473	0.0	522	13.7	571	0.0
425	0.0	474	0.0	523	16.0	572	0.0
426	0.0	475	0.0	524	18.1	573	0.0
427	0.0	476	0.0	525	20.8	574	0.0
428	0.0	477	0.0	526	21.5	575	0.0
429	0.0	478	0.0	527	22.5	576	0.0
430	0.0	479	0.0	528	23.4	577	0.0
431	0.0	480	0.0	529	24.5	578	0.0
432	0.0	481	1.4	530	25.6	579	0.0
580	0.0						

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
581	0.0						
582	0.0						
583	0.0						
584	0.0						
585	0.0						
586	0.0						
587	0.0						
588	0.0						
589	0.0						

Table A1/4

WLTC, Class 2 vehicles, phase Medium2

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
590	0.0	637	38.6	684	59.3	731	55.3
591	0.0	638	39.8	685	60.2	732	55.1
592	0.0	639	40.6	686	61.3	733	54.8
593	0.0	640	41.1	687	62.4	734	54.6
594	0.0	641	41.9	688	63.4	735	54.5
595	0.0	642	42.8	689	64.4	736	54.3
596	0.0	643	44.3	690	65.4	737	53.9
597	0.0	644	45.7	691	66.3	738	53.4
598	0.0	645	47.4	692	67.2	739	52.6
599	0.0	646	48.9	693	68.0	740	51.5
600	0.0	647	50.6	694	68.8	741	50.2
601	1.6	648	52.0	695	69.5	742	48.7
602	3.6	649	53.7	696	70.1	743	47.0
603	6.3	650	55.0	697	70.6	744	45.1
604	9.0	651	56.8	698	71.0	745	43.0
605	11.8	652	58.0	699	71.6	746	40.6
606	14.2	653	59.8	700	72.2	747	38.1
607	16.6	654	61.1	701	72.8	748	35.4
608	18.5	655	62.4	702	73.5	749	32.7
609	20.8	656	63.0	703	74.1	750	30.0
610	23.4	657	63.5	704	74.3	751	27.5
611	26.9	658	63.0	705	74.3	752	25.3
612	30.3	659	62.0	706	73.7	753	23.4
613	32.8	660	60.4	707	71.9	754	22.0
614	34.1	661	58.6	708	70.5	755	20.8
615	34.2	662	56.7	709	68.9	756	19.8
616	33.6	663	55.0	710	67.4	757	18.9
617	32.1	664	53.7	711	66.0	758	18.0
618	30.0	665	52.7	712	64.7	759	17.0
619	27.5	666	51.9	713	63.7	760	16.1
620	25.1	667	51.4	714	62.9	761	15.5
621	22.8	668	51.0	715	62.2	762	14.4
622	20.5	669	50.7	716	61.7	763	14.9
623	17.9	670	50.6	717	61.2	764	15.9
624	15.1	671	50.8	718	60.7	765	17.1
625	13.4	672	51.2	719	60.3	766	18.3
626	12.8	673	51.7	720	59.9	767	19.4
627	13.7	674	52.3	721	59.6	768	20.4
628	16.0	675	53.1	722	59.3	769	21.2
629	18.1	676	53.8	723	59.0	770	21.9
630	20.8	677	54.5	724	58.6	771	22.7
631	23.7	678	55.1	725	58.0	772	23.4
632	26.5	679	55.9	726	57.5	773	24.2
633	29.3	680	56.5	727	56.9	774	24.3
634	32.0	681	57.1	728	56.3	775	24.2
635	34.5	682	57.8	729	55.9	776	24.1
636	36.8	683	58.5	730	55.6	777	23.8

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
778	23.0	827	59.9	876	46.9	925	49.0
779	22.6	828	60.7	877	47.1	926	48.5
780	21.7	829	61.4	878	47.5	927	48.0
781	21.3	830	62.0	879	47.8	928	47.5
782	20.3	831	62.5	880	48.3	929	47.0
783	19.1	832	62.9	881	48.8	930	46.9
784	18.1	833	63.2	882	49.5	931	46.8
785	16.9	834	63.4	883	50.2	932	46.8
786	16.0	835	63.7	884	50.8	933	46.8
787	14.8	836	64.0	885	51.4	934	46.9
788	14.5	837	64.4	886	51.8	935	46.9
789	13.7	838	64.9	887	51.9	936	46.9
790	13.5	839	65.5	888	51.7	937	46.9
791	12.9	840	66.2	889	51.2	938	46.9
792	12.7	841	67.0	890	50.4	939	46.8
793	12.5	842	67.8	891	49.2	940	46.6
794	12.5	843	68.6	892	47.7	941	46.4
795	12.6	844	69.4	893	46.3	942	46.0
796	13.0	845	70.1	894	45.1	943	45.5
797	13.6	846	70.9	895	44.2	944	45.0
798	14.6	847	71.7	896	43.7	945	44.5
799	15.7	848	72.5	897	43.4	946	44.2
800	17.1	849	73.2	898	43.1	947	43.9
801	18.7	850	73.8	899	42.5	948	43.7
802	20.2	851	74.4	900	41.8	949	43.6
803	21.9	852	74.7	901	41.1	950	43.6
804	23.6	853	74.7	902	40.3	951	43.5
805	25.4	854	74.6	903	39.7	952	43.5
806	27.1	855	74.2	904	39.3	953	43.4
807	28.9	856	73.5	905	39.2	954	43.3
808	30.4	857	72.6	906	39.3	955	43.1
809	32.0	858	71.8	907	39.6	956	42.9
810	33.4	859	71.0	908	40.0	957	42.7
811	35.0	860	70.1	909	40.7	958	42.5
812	36.4	861	69.4	910	41.4	959	42.4
813	38.1	862	68.9	911	42.2	960	42.2
814	39.7	863	68.4	912	43.1	961	42.1
815	41.6	864	67.9	913	44.1	962	42.0
816	43.3	865	67.1	914	44.9	963	41.8
817	45.1	866	65.8	915	45.6	964	41.7
818	46.9	867	63.9	916	46.4	965	41.5
819	48.7	868	61.4	917	47.0	966	41.3
820	50.5	869	58.4	918	47.8	967	41.1
821	52.4	870	55.4	919	48.3	968	40.8
822	54.1	871	52.4	920	48.9	969	40.3
823	55.7	872	50.0	921	49.4	970	39.6
824	56.8	873	48.3	922	49.8	971	38.5
825	57.9	874	47.3	923	49.6	972	37.0

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
826	59.0	875	46.8	924	49.3	973	35.1
974	33.0						
975	30.6						
976	27.9						
977	25.1						
978	22.0						
979	18.8						
980	15.5						
981	12.3						
982	8.8						
983	6.0						
984	3.6						
985	1.6						
986	0.0						
987	0.0						
988	0.0						
989	0.0						
990	0.0						
991	0.0						
992	0.0						
993	0.0						
994	0.0						
995	0.0						
996	0.0						
997	0.0						
998	0.0						
999	0.0						
1000	0.0						
1001	0.0						
1002	0.0						
1003	0.0						
1004	0.0						
1005	0.0						
1006	0.0						
1007	0.0						
1008	0.0						
1009	0.0						
1010	0.0						
1011	0.0						
1012	0.0						
1013	0.0						
1014	0.0						
1015	0.0						
1016	0.0						
1017	0.0						
1018	0.0						
1019	0.0						
1020	0.0						
1021	0.0						

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1022	0.0						

Table A1/5

WLTC, Class 2 vehicles, phase High$_2$

Deleted:

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1023	0.0	1070	46.0	1117	73.9	1164	71.7
1024	0.0	1071	46.4	1118	74.9	1165	69.9
1025	0.0	1072	47.0	1119	75.7	1166	67.9
1026	0.0	1073	47.4	1120	76.4	1167	65.7
1027	1.1	1074	48.0	1121	77.1	1168	63.5
1028	3.0	1075	48.4	1122	77.6	1169	61.2
1029	5.7	1076	49.0	1123	78.0	1170	59.0
1030	8.4	1077	49.4	1124	78.2	1171	56.8
1031	11.1	1078	50.0	1125	78.4	1172	54.7
1032	14.0	1079	50.4	1126	78.5	1173	52.7
1033	17.0	1080	50.8	1127	78.5	1174	50.9
1034	20.1	1081	51.1	1128	78.6	1175	49.4
1035	22.7	1082	51.3	1129	78.7	1176	48.1
1036	23.6	1083	51.3	1130	78.9	1177	47.1
1037	24.5	1084	51.3	1131	79.1	1178	46.5
1038	24.8	1085	51.3	1132	79.4	1179	46.3
1039	25.1	1086	51.3	1133	79.8	1180	46.5
1040	25.3	1087	51.3	1134	80.1	1181	47.2
1041	25.5	1088	51.3	1135	80.5	1182	48.3
1042	25.7	1089	51.4	1136	80.8	1183	49.7
1043	25.8	1090	51.6	1137	81.0	1184	51.3
1044	25.9	1091	51.8	1138	81.2	1185	53.0
1045	26.0	1092	52.1	1139	81.3	1186	54.9
1046	26.1	1093	52.3	1140	81.2	1187	56.7
1047	26.3	1094	52.6	1141	81.0	1188	58.6
1048	26.5	1095	52.8	1142	80.6	1189	60.2
1049	26.8	1096	52.9	1143	80.0	1190	61.6
1050	27.1	1097	53.0	1144	79.1	1191	62.2
1051	27.5	1098	53.0	1145	78.0	1192	62.5
1052	28.0	1099	53.0	1146	76.8	1193	62.8
1053	28.6	1100	53.1	1147	75.5	1194	62.9
1054	29.3	1101	53.2	1148	74.1	1195	63.0
1055	30.4	1102	53.3	1149	72.9	1196	63.0
1056	31.8	1103	53.4	1150	71.9	1197	63.1
1057	33.7	1104	53.5	1151	71.2	1198	63.2
1058	35.8	1105	53.7	1152	70.9	1199	63.3
1059	37.8	1106	55.0	1153	71.0	1200	63.5
1060	39.5	1107	56.8	1154	71.5	1201	63.7
1061	40.8	1108	58.8	1155	72.3	1202	63.9
1062	41.8	1109	60.9	1156	73.2	1203	64.1
1063	42.4	1110	63.0	1157	74.1	1204	64.3
1064	43.0	1111	65.0	1158	74.9	1205	66.1
1065	43.4	1112	66.9	1159	75.4	1206	67.9

Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1066	44.0	1113	68.6	1160	75.5	1207	69.7
1067	44.4	1114	70.1	1161	75.2	1208	71.4
1068	45.0	1115	71.5	1162	74.5	1209	73.1
1069	45.4	1116	72.8	1163	73.3	1210	74.7
1211	76.2	1260	35.4	1309	72.3	1358	70.8
1212	77.5	1261	32.7	1310	71.9	1359	70.8
1213	78.6	1262	30.0	1311	71.3	1360	70.9
1214	79.7	1263	29.9	1312	70.9	1361	70.9
1215	80.6	1264	30.0	1313	70.5	1362	70.9
1216	81.5	1265	30.2	1314	70.0	1363	70.9
1217	82.2	1266	30.4	1315	69.6	1364	71.0
1218	83.0	1267	30.6	1316	69.2	1365	71.0
1219	83.7	1268	31.6	1317	68.8	1366	71.1
1220	84.4	1269	33.0	1318	68.4	1367	71.2
1221	84.9	1270	33.9	1319	67.9	1368	71.3
1222	85.1	1271	34.8	1320	67.5	1369	71.4
1223	85.2	1272	35.7	1321	67.2	1370	71.5
1224	84.9	1273	36.6	1322	66.8	1371	71.7
1225	84.4	1274	37.5	1323	65.6	1372	71.8
1226	83.6	1275	38.4	1324	63.3	1373	71.9
1227	82.7	1276	39.3	1325	60.2	1374	71.9
1228	81.5	1277	40.2	1326	56.2	1375	71.9
1229	80.1	1278	40.8	1327	52.2	1376	71.9
1230	78.7	1279	41.7	1328	48.4	1377	71.9
1231	77.4	1280	42.4	1329	45.0	1378	71.9
1232	76.2	1281	43.1	1330	41.6	1379	71.9
1233	75.4	1282	43.6	1331	38.6	1380	72.0
1234	74.8	1283	44.2	1332	36.4	1381	72.1
1235	74.3	1284	44.8	1333	34.8	1382	72.4
1236	73.8	1285	45.5	1334	34.2	1383	72.7
1237	73.2	1286	46.3	1335	34.7	1384	73.1
1238	72.4	1287	47.2	1336	36.3	1385	73.4
1239	71.6	1288	48.1	1337	38.5	1386	73.8
1240	70.8	1289	49.1	1338	41.0	1387	74.0
1241	69.9	1290	50.0	1339	43.7	1388	74.1
1242	67.9	1291	51.0	1340	46.5	1389	74.0
1243	65.7	1292	51.9	1341	49.1	1390	73.0
1244	63.5	1293	52.7	1342	51.6	1391	72.0
1245	61.2	1294	53.7	1343	53.9	1392	71.0
1246	59.0	1295	55.0	1344	56.0	1393	70.0
1247	56.8	1296	56.8	1345	57.9	1394	69.0
1248	54.7	1297	58.8	1346	59.7	1395	68.0
1249	52.7	1298	60.9	1347	61.2	1396	67.7
1250	50.9	1299	63.0	1348	62.5	1397	66.7
1251	49.4	1300	65.0	1349	63.5	1398	66.6
1252	48.1	1301	66.9	1350	64.3	1399	66.7
1253	47.1	1302	68.6	1351	65.3	1400	66.8
1254	46.5	1303	70.1	1352	66.3	1401	66.9
1255	46.3	1304	71.0	1353	67.3	1402	66.9

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1256	45.1	1305	71.8	1354	68.3	1403	66.9
1257	43.0	1306	72.8	1355	69.3	1404	66.9
1258	40.6	1307	72.9	1356	70.3	1405	66.9
1259	38.1	1308	73.0	1357	70.8	1406	66.9
1407	66.9	1456	0.0				
1408	67.0	1457	0.0				
1409	67.1	1458	0.0				
1410	67.3	1459	0.0				
1411	67.5	1460	0.0				
1412	67.8	1461	0.0				
1413	68.2	1462	0.0				
1414	68.6	1463	0.0				
1415	69.0	1464	0.0				
1416	69.3	1465	0.0				
1417	69.3	1466	0.0				
1418	69.2	1467	0.0				
1419	68.8	1468	0.0				
1420	68.2	1469	0.0				
1421	67.6	1470	0.0				
1422	67.4	1471	0.0				
1423	67.2	1472	0.0				
1424	66.9	1473	0.0				
1425	66.3	1474	0.0				
1426	65.4	1475	0.0				
1427	64.0	1476	0.0				
1428	62.4	1477	0.0				
1429	60.6						
1430	58.6						
1431	56.7						
1432	54.8						
1433	53.0						
1434	51.3						
1435	49.6						
1436	47.8						
1437	45.5						
1438	42.8						
1439	39.8						
1440	36.5						
1441	33.0						
1442	29.5						
1443	25.8						
1444	22.1						
1445	18.6						
1446	15.3						
1447	12.4						
1448	9.6						
1449	6.6						
1450	3.8						

Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1451	1.6						
1452	0.0						
1453	0.0						
1454	0.0						
1455	0.0						

Table A1/6

WLTC, Class 2 vehicles, phase Extra High$_2$

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Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1478	0.0	1525	63.4	1572	107.4	1619	113.7
1479	1.1	1526	64.5	1573	108.7	1620	114.1
1480	2.3	1527	65.7	1574	109.9	1621	114.4
1481	4.6	1528	66.9	1575	111.2	1622	114.6
1482	6.5	1529	68.1	1576	112.3	1623	114.7
1483	8.9	1530	69.1	1577	113.4	1624	114.7
1484	10.9	1531	70.0	1578	114.4	1625	114.7
1485	13.5	1532	70.9	1579	115.3	1626	114.6
1486	15.2	1533	71.8	1580	116.1	1627	114.5
1487	17.6	1534	72.6	1581	116.8	1628	114.5
1488	19.3	1535	73.4	1582	117.4	1629	114.5
1489	21.4	1536	74.0	1583	117.7	1630	114.7
1490	23.0	1537	74.7	1584	118.2	1631	115.0
1491	25.0	1538	75.2	1585	118.1	1632	115.6
1492	26.5	1539	75.7	1586	117.7	1633	116.4
1493	28.4	1540	76.4	1587	117.0	1634	117.3
1494	29.8	1541	77.2	1588	116.1	1635	118.2
1495	31.7	1542	78.2	1589	115.2	1636	118.8
1496	33.7	1543	78.9	1590	114.4	1637	119.3
1497	35.8	1544	79.9	1591	113.6	1638	119.6
1498	38.1	1545	81.1	1592	113.0	1639	119.7
1499	40.5	1546	82.4	1593	112.6	1640	119.5
1500	42.2	1547	83.7	1594	112.2	1641	119.3
1501	43.5	1548	85.4	1595	111.9	1642	119.2
1502	44.5	1549	87.0	1596	111.6	1643	119.0
1503	45.2	1550	88.3	1597	111.2	1644	118.8
1504	45.8	1551	89.5	1598	110.7	1645	118.8
1505	46.6	1552	90.5	1599	110.1	1646	118.8
1506	47.4	1553	91.3	1600	109.3	1647	118.8
1507	48.5	1554	92.2	1601	108.4	1648	118.8
1508	49.7	1555	93.0	1602	107.4	1649	118.9
1509	51.3	1556	93.8	1603	106.7	1650	119.0
1510	52.9	1557	94.6	1604	106.3	1651	119.0
1511	54.3	1558	95.3	1605	106.2	1652	119.1
1512	55.6	1559	95.9	1606	106.4	1653	119.2
1513	56.8	1560	96.6	1607	107.0	1654	119.4
1514	57.9	1561	97.4	1608	107.5	1655	119.6
1515	58.9	1562	98.1	1609	107.9	1656	119.9
1516	59.7	1563	98.7	1610	108.4	1657	120.1
1517	60.3	1564	99.5	1611	108.9	1658	120.3

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1518	60.7	1565	100.3	1612	109.5	1659	120.4
1519	60.9	1566	101.1	1613	110.2	1660	120.5
1520	61.0	1567	101.9	1614	110.9	1661	120.5
1521	61.1	1568	102.8	1615	111.6	1662	120.5
1522	61.4	1569	103.8	1616	112.2	1663	120.5
1523	61.8	1570	105.0	1617	112.8	1664	120.4
1524	62.5	1571	106.1	1618	113.3	1665	120.3
1666	120.1	1715	120.4	1764	82.6		
1667	119.9	1716	120.8	1765	81.9		
1668	119.6	1717	121.1	1766	81.1		
1669	119.5	1718	121.6	1767	80.0		
1670	119.4	1719	121.8	1768	78.7		
1671	119.3	1720	122.1	1769	76.9		
1672	119.3	1721	122.4	1770	74.6		
1673	119.4	1722	122.7	1771	72.0		
1674	119.5	1723	122.8	1772	69.0		
1675	119.5	1724	123.1	1773	65.6		
1676	119.6	1725	123.1	1774	62.1		
1677	119.6	1726	122.8	1775	58.5		
1678	119.6	1727	122.3	1776	54.7		
1679	119.4	1728	121.3	1777	50.9		
1680	119.3	1729	119.9	1778	47.3		
1681	119.0	1730	118.1	1779	43.8		
1682	118.8	1731	115.9	1780	40.4		
1683	118.7	1732	113.5	1781	37.4		
1684	118.8	1733	111.1	1782	34.3		
1685	119.0	1734	108.6	1783	31.3		
1686	119.2	1735	106.2	1784	28.3		
1687	119.6	1736	104.0	1785	25.2		
1688	120.0	1737	101.1	1786	22.0		
1689	120.3	1738	98.3	1787	18.9		
1690	120.5	1739	95.7	1788	16.1		
1691	120.7	1740	93.5	1789	13.4		
1692	120.9	1741	91.5	1790	11.1		
1693	121.0	1742	90.7	1791	8.9		
1694	121.1	1743	90.4	1792	6.9		
1695	121.2	1744	90.2	1793	4.9		
1696	121.3	1745	90.2	1794	2.8		
1697	121.4	1746	90.1	1795	0.0		
1698	121.5	1747	90.0	1796	0.0		
1699	121.5	1748	89.8	1797	0.0		
1700	121.5	1749	89.6	1798	0.0		
1701	121.4	1750	89.4	1799	0.0		
1702	121.3	1751	89.2	1800	0.0		
1703	121.1	1752	88.9				
1704	120.9	1753	88.5				
1705	120.6	1754	88.1				
1706	120.4	1755	87.6				

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1707	120.2	1756	87.1				
1708	120.1	1757	86.6				
1709	119.9	1758	86.1				
1710	119.8	1759	85.5				
1711	119.8	1760	85.0				
1712	119.9	1761	84.4				
1713	120.0	1762	83.8				
1714	120.2	1763	83.2				

6. WLTC for Class 3 vehicles

Figure A1/7

WLTC, Class 3 vehicles, phase Low$_3$

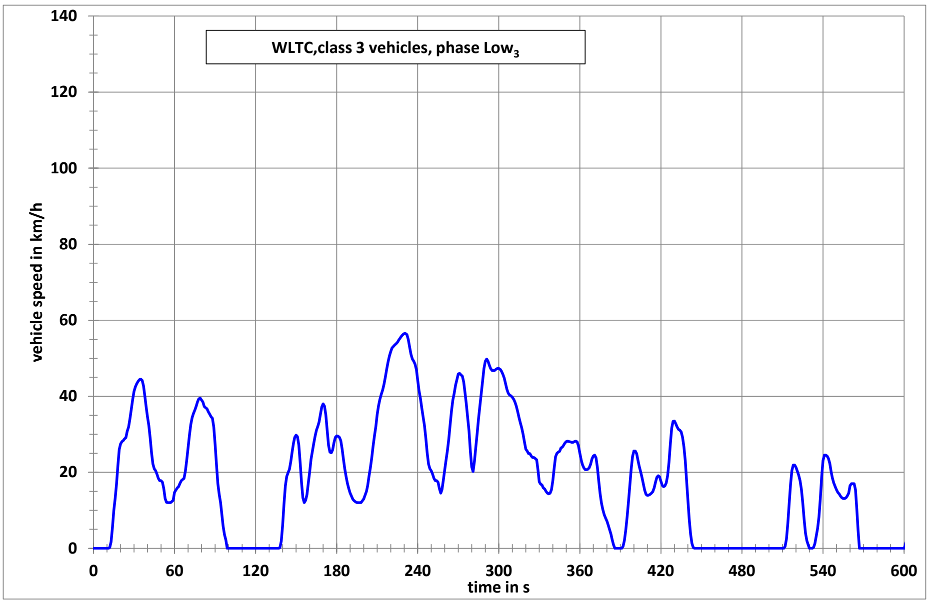

Figure A1/8

WLTC, Class 3 vehicles, phase Medium$_{3-1}$

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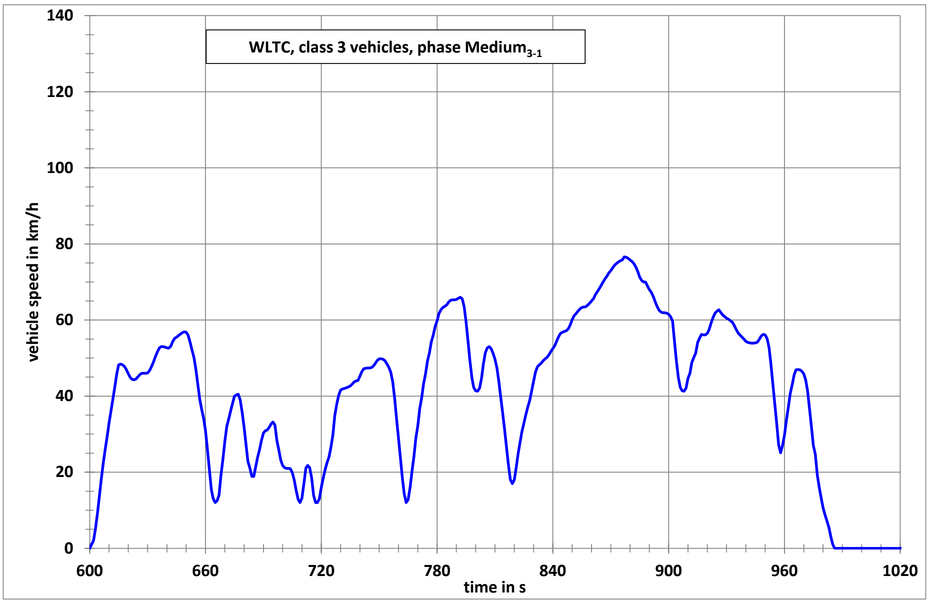

Figure A1/9

WLTC, Class 3 vehicles, phase $Medium_{3-2}$

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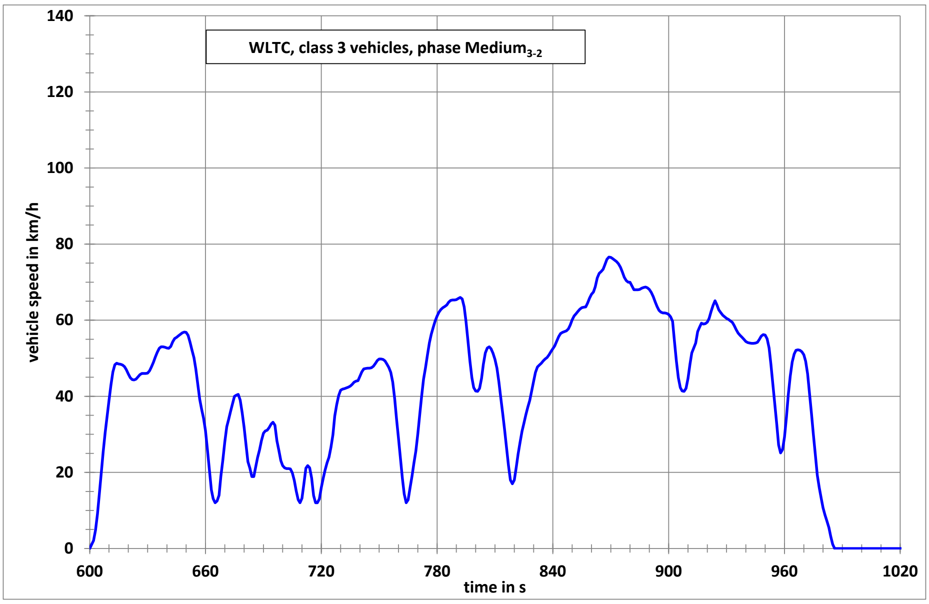

Figure A1/10

WLTC, Class 3 vehicles, phase $High_{3-1}$

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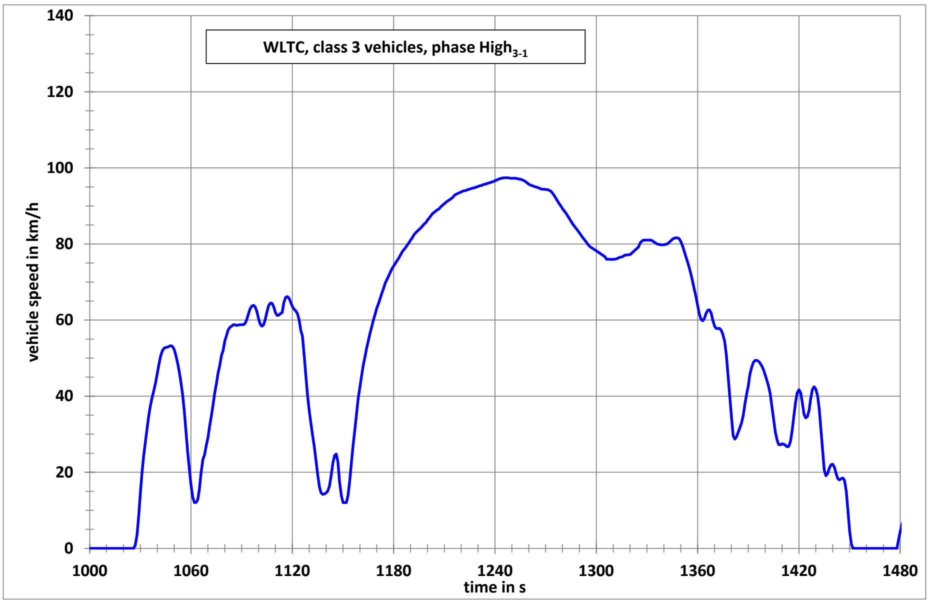

Figure A1/11

WLTC, Class 3 vehicles, phase High$_{3-2}$

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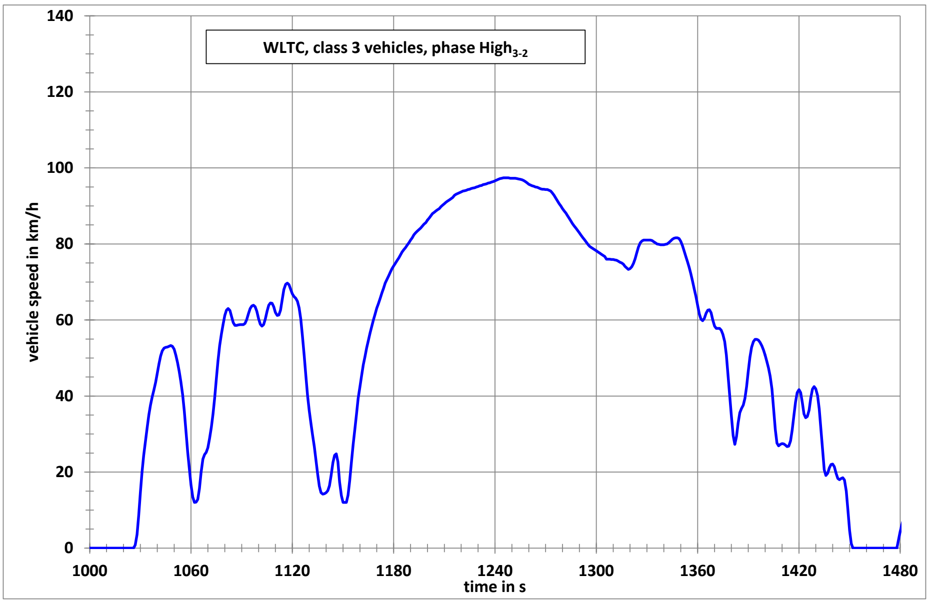

Figure A1/12

WLTC, Class 3 vehicles, phase Extra High$_3$

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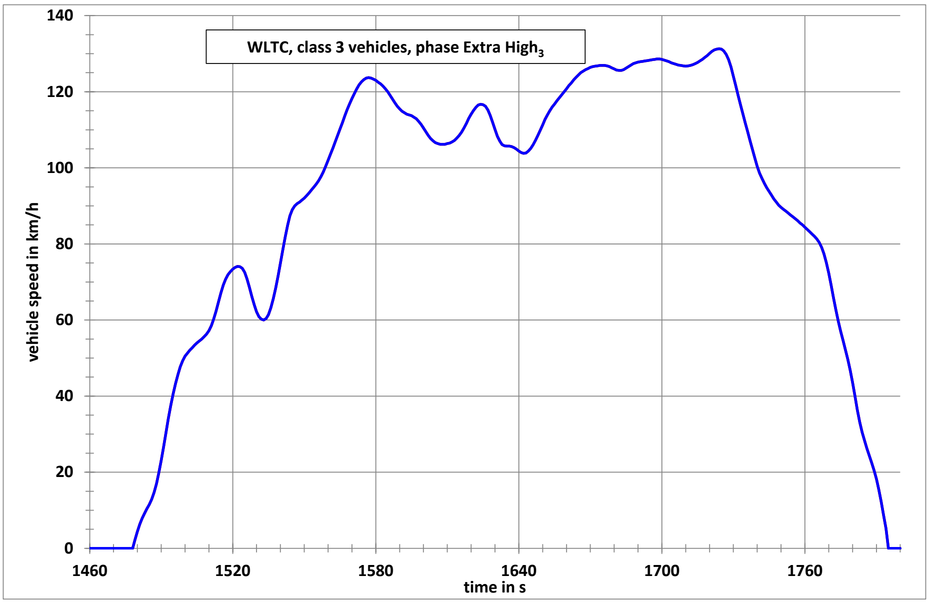

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Table A1/7

WLTC, Class 3 vehicles, phase Low$_3$

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
0	0.0	47	19.5	94	12.0	141	11.7
1	0.0	48	18.4	95	9.1	142	16.4
2	0.0	49	17.8	96	5.8	143	18.9
3	0.0	50	17.8	97	3.6	144	19.9
4	0.0	51	17.4	98	2.2	145	20.8
5	0.0	52	15.7	99	0.0	146	22.8
6	0.0	53	13.1	100	0.0	147	25.4
7	0.0	54	12.1	101	0.0	148	27.7
8	0.0	55	12.0	102	0.0	149	29.2
9	0.0	56	12.0	103	0.0	150	29.8
10	0.0	57	12.0	104	0.0	151	29.4
11	0.0	58	12.3	105	0.0	152	27.2
12	0.2	59	12.6	106	0.0	153	22.6
13	1.7	60	14.7	107	0.0	154	17.3
14	5.4	61	15.3	108	0.0	155	13.3
15	9.9	62	15.9	109	0.0	156	12.0
16	13.1	63	16.2	110	0.0	157	12.6
17	16.9	64	17.1	111	0.0	158	14.1
18	21.7	65	17.8	112	0.0	159	17.2
19	26.0	66	18.1	113	0.0	160	20.1
20	27.5	67	18.4	114	0.0	161	23.4
21	28.1	68	20.3	115	0.0	162	25.5
22	28.3	69	23.2	116	0.0	163	27.6

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
23	28.8	70	26.5	117	0.0	164	29.5
24	29.1	71	29.8	118	0.0	165	31.1
25	30.8	72	32.6	119	0.0	166	32.1
26	31.9	73	34.4	120	0.0	167	33.2
27	34.1	74	35.5	121	0.0	168	35.2
28	36.6	75	36.4	122	0.0	169	37.2
29	39.1	76	37.4	123	0.0	170	38.0
30	41.3	77	38.5	124	0.0	171	37.4
31	42.5	78	39.3	125	0.0	172	35.1
32	43.3	79	39.5	126	0.0	173	31.0
33	43.9	80	39.0	127	0.0	174	27.1
34	44.4	81	38.5	128	0.0	175	25.3
35	44.5	82	37.3	129	0.0	176	25.1
36	44.2	83	37.0	130	0.0	177	25.9
37	42.7	84	36.7	131	0.0	178	27.8
38	39.9	85	35.9	132	0.0	179	29.2
39	37.0	86	35.3	133	0.0	180	29.6
40	34.6	87	34.6	134	0.0	181	29.5
41	32.3	88	34.2	135	0.0	182	29.2
42	29.0	89	31.9	136	0.0	183	28.3
43	25.1	90	27.3	137	0.0	184	26.1
44	22.2	91	22.0	138	0.2	185	23.6
45	20.9	92	17.0	139	1.9	186	21.0
46	20.4	93	14.2	140	6.1	187	18.9
188	17.1	237	49.2	286	37.4	335	15.0
189	15.7	238	48.4	287	40.7	336	14.5
190	14.5	239	46.9	288	44.0	337	14.3
191	13.7	240	44.3	289	47.3	338	14.5
192	12.9	241	41.5	290	49.2	339	15.4
193	12.5	242	39.5	291	49.8	340	17.8
194	12.2	243	37.0	292	49.2	341	21.1
195	12.0	244	34.6	293	48.1	342	24.1
196	12.0	245	32.3	294	47.3	343	25.0
197	12.0	246	29.0	295	46.8	344	25.3
198	12.0	247	25.1	296	46.7	345	25.5
199	12.5	248	22.2	297	46.8	346	26.4
200	13.0	249	20.9	298	47.1	347	26.6
201	14.0	250	20.4	299	47.3	348	27.1
202	15.0	251	19.5	300	47.3	349	27.7
203	16.5	252	18.4	301	47.1	350	28.1
204	19.0	253	17.8	302	46.6	351	28.2
205	21.2	254	17.8	303	45.8	352	28.1
206	23.8	255	17.4	304	44.8	353	28.0
207	26.9	256	15.7	305	43.3	354	27.9
208	29.6	257	14.5	306	41.8	355	27.9
209	32.0	258	15.4	307	40.8	356	28.1
210	35.2	259	17.9	308	40.3	357	28.2
211	37.5	260	20.6	309	40.1	358	28.0
212	39.2	261	23.2	310	39.7	359	26.9

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
213	40.5	262	25.7	311	39.2	360	25.0
214	41.6	263	28.7	312	38.5	361	23.2
215	43.1	264	32.5	313	37.4	362	21.9
216	45.0	265	36.1	314	36.0	363	21.1
217	47.1	266	39.0	315	34.4	364	20.7
218	49.0	267	40.8	316	33.0	365	20.7
219	50.6	268	42.9	317	31.7	366	20.8
220	51.8	269	44.4	318	30.0	367	21.2
221	52.7	270	45.9	319	28.0	368	22.1
222	53.1	271	46.0	320	26.1	369	23.5
223	53.5	272	45.6	321	25.6	370	24.3
224	53.8	273	45.3	322	24.9	371	24.5
225	54.2	274	43.7	323	24.9	372	23.8
226	54.8	275	40.8	324	24.3	373	21.3
227	55.3	276	38.0	325	23.9	374	17.7
228	55.8	277	34.4	326	23.9	375	14.4
229	56.2	278	30.9	327	23.6	376	11.9
230	56.5	279	25.5	328	23.3	377	10.2
231	56.5	280	21.4	329	20.5	378	8.9
232	56.2	281	20.2	330	17.5	379	8.0
233	54.9	282	22.9	331	16.9	380	7.2
234	52.9	283	26.6	332	16.7	381	6.1
235	51.0	284	30.2	333	15.9	382	4.9
236	49.8	285	34.1	334	15.6	383	3.7
384	2.3	433	31.3	482	0.0	531	0.0
385	0.9	434	31.1	483	0.0	532	0.0
386	0.0	435	30.6	484	0.0	533	0.2
387	0.0	436	29.2	485	0.0	534	1.2
388	0.0	437	26.7	486	0.0	535	3.2
389	0.0	438	23.0	487	0.0	536	5.2
390	0.0	439	18.2	488	0.0	537	8.2
391	0.0	440	12.9	489	0.0	538	13
392	0.5	441	7.7	490	0.0	539	18.8
393	2.1	442	3.8	491	0.0	540	23.1
394	4.8	443	1.3	492	0.0	541	24.5
395	8.3	444	0.2	493	0.0	542	24.5
396	12.3	445	0.0	494	0.0	543	24.3
397	16.6	446	0.0	495	0.0	544	23.6
398	20.9	447	0.0	496	0.0	545	22.3
399	24.2	448	0.0	497	0.0	546	20.1
400	25.6	449	0.0	498	0.0	547	18.5
401	25.6	450	0.0	499	0.0	548	17.2
402	24.9	451	0.0	500	0.0	549	16.3
403	23.3	452	0.0	501	0.0	550	15.4
404	21.6	453	0.0	502	0.0	551	14.7
405	20.2	454	0.0	503	0.0	552	14.3
406	18.7	455	0.0	504	0.0	553	13.7
407	17.0	456	0.0	505	0.0	554	13.3

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
408	15.3	457	0.0	506	0.0	555	13.1
409	14.2	458	0.0	507	0.0	556	13.1
410	13.9	459	0.0	508	0.0	557	13.3
411	14.0	460	0.0	509	0.0	558	13.8
412	14.2	461	0.0	510	0.0	559	14.5
413	14.5	462	0.0	511	0.0	560	16.5
414	14.9	463	0.0	512	0.5	561	17.0
415	15.9	464	0.0	513	2.5	562	17.0
416	17.4	465	0.0	514	6.6	563	17.0
417	18.7	466	0.0	515	11.8	564	15.4
418	19.1	467	0.0	516	16.8	565	10.1
419	18.8	468	0.0	517	20.5	566	4.8
420	17.6	469	0.0	518	21.9	567	0.0
421	16.6	470	0.0	519	21.9	568	0.0
422	16.2	471	0.0	520	21.3	569	0.0
423	16.4	472	0.0	521	20.3	570	0.0
424	17.2	473	0.0	522	19.2	571	0.0
425	19.1	474	0.0	523	17.8	572	0.0
426	22.6	475	0.0	524	15.5	573	0.0
427	27.4	476	0.0	525	11.9	574	0.0
428	31.6	477	0.0	526	7.6	575	0.0
429	33.4	478	0.0	527	4.0	576	0.0
430	33.5	479	0.0	528	2.0	577	0.0
431	32.8	480	0.0	529	1.0	578	0.0
432	31.9	481	0.0	530	0.0	579	0.0
580	0.0						
581	0.0						
582	0.0						
583	0.0						
584	0.0						
585	0.0						
586	0.0						
587	0.0						
588	0.0						
589	0.0						

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*

Table A1/8

WLTC, Class 3 vehicles, phase Medium$_{3-1}$

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
590	0.0	637	53.0	684	18.9	731	41.9
591	0.0	638	53.0	685	18.9	732	42.0
592	0.0	639	52.9	686	21.3	733	42.2
593	0.0	640	52.7	687	23.9	734	42.4
594	0.0	641	52.6	688	25.9	735	42.7
595	0.0	642	53.1	689	28.4	736	43.1
596	0.0	643	54.3	690	30.3	737	43.7
597	0.0	644	55.2	691	30.9	738	44.0
598	0.0	645	55.5	692	31.1	739	44.1
599	0.0	646	55.9	693	31.8	740	45.3
600	0.0	647	56.3	694	32.7	741	46.4
601	1.0	648	56.7	695	33.2	742	47.2
602	2.1	649	56.9	696	32.4	743	47.3
603	5.2	650	56.8	697	28.3	744	47.4
604	9.2	651	56.0	698	25.8	745	47.4
605	13.5	652	54.2	699	23.1	746	47.5
606	18.1	653	52.1	700	21.8	747	47.9
607	22.3	654	50.1	701	21.2	748	48.6
608	26.0	655	47.2	702	21.0	749	49.4

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
609	29.3	656	43.2	703	21.0	750	49.8
610	32.8	657	39.2	704	20.9	751	49.8
611	36.0	658	36.5	705	19.9	752	49.7
612	39.2	659	34.3	706	17.9	753	49.3
613	42.5	660	31.0	707	15.1	754	48.5
614	45.7	661	26.0	708	12.8	755	47.6
615	48.2	662	20.7	709	12.0	756	46.3
616	48.4	663	15.4	710	13.2	757	43.7
617	48.2	664	13.1	711	17.1	758	39.3
618	47.8	665	12.0	712	21.1	759	34.1
619	47.0	666	12.5	713	21.8	760	29.0
620	45.9	667	14.0	714	21.2	761	23.7
621	44.9	668	19.0	715	18.5	762	18.4
622	44.4	669	23.2	716	13.9	763	14.3
623	44.3	670	28.0	717	12.0	764	12.0
624	44.5	671	32.0	718	12.0	765	12.8
625	45.1	672	34.0	719	13.0	766	16.0
626	45.7	673	36.0	720	16.3	767	20.4
627	46.0	674	38.0	721	20.5	768	24.0
628	46.0	675	40.0	722	23.9	769	29.0
629	46.0	676	40.3	723	26.0	770	32.2
630	46.1	677	40.5	724	28.0	771	36.8
631	46.7	678	39.0	725	31.5	772	39.4
632	47.7	679	35.7	726	33.4	773	43.2
633	48.9	680	31.8	727	36.0	774	45.8
634	50.3	681	27.1	728	37.8	775	49.2
635	51.6	682	22.8	729	40.2	776	51.4
636	52.6	683	21.1	730	41.6	777	54.2
778	56.0	827	37.1	876	75.8	925	62.3
779	58.3	828	38.9	877	76.6	926	62.7
780	59.8	829	41.4	878	76.5	927	62.0
781	61.7	830	44.0	879	76.2	928	61.3
782	62.7	831	46.3	880	75.8	929	60.9
783	63.3	832	47.7	881	75.4	930	60.5
784	63.6	833	48.2	882	74.8	931	60.2
785	64.0	834	48.7	883	73.9	932	59.8
786	64.7	835	49.3	884	72.7	933	59.4
787	65.2	836	49.8	885	71.3	934	58.6
788	65.3	837	50.2	886	70.4	935	57.5
789	65.3	838	50.9	887	70.0	936	56.6
790	65.4	839	51.8	888	70.0	937	56.0
791	65.7	840	52.5	889	69.0	938	55.5
792	66.0	841	53.3	890	68.0	939	55.0
793	65.6	842	54.5	891	67.3	940	54.4
794	63.5	843	55.7	892	66.2	941	54.1
795	59.7	844	56.5	893	64.8	942	54.0
796	54.6	845	56.8	894	63.6	943	53.9
797	49.3	846	57.0	895	62.6	944	53.9
798	44.9	847	57.2	896	62.1	945	54.0

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
799	42.3	848	57.7	897	61.9	946	54.2
800	41.4	849	58.7	898	61.9	947	55.0
801	41.3	850	60.1	899	61.8	948	55.8
802	43.0	851	61.1	900	61.5	949	56.2
803	45.0	852	61.7	901	60.9	950	56.1
804	46.5	853	62.3	902	59.7	951	55.1
805	48.3	854	62.9	903	54.6	952	52.7
806	49.5	855	63.3	904	49.3	953	48.4
807	51.2	856	63.4	905	44.9	954	43.1
808	52.2	857	63.5	906	42.3	955	37.8
809	51.6	858	63.9	907	41.4	956	32.5
810	49.7	859	64.4	908	41.3	957	27.2
811	47.4	860	65.0	909	42.1	958	25.1
812	43.7	861	65.6	910	44.7	959	27.0
813	39.7	862	66.6	911	46.0	960	29.8
814	35.5	863	67.4	912	48.8	961	33.8
815	31.1	864	68.2	913	50.1	962	37.0
816	26.3	865	69.1	914	51.3	963	40.7
817	21.9	866	70.0	915	54.1	964	43.0
818	18.0	867	70.8	916	55.2	965	45.6
819	17.0	868	71.5	917	56.2	966	46.9
820	18.0	869	72.4	918	56.1	967	47.0
821	21.4	870	73.0	919	56.1	968	46.9
822	24.8	871	73.7	920	56.5	969	46.5
823	27.9	872	74.4	921	57.5	970	45.8
824	30.8	873	74.9	922	59.2	971	44.3
825	33.0	874	75.3	923	60.7	972	41.3
826	35.1	875	75.6	924	61.8	973	36.5

974	31.7
975	27.0
976	24.7
977	19.3
978	16.0
979	13.2
980	10.7
981	8.8
982	7.2
983	5.5
984	3.2
985	1.1
986	0.0
987	0.0
988	0.0
989	0.0
990	0.0
991	0.0
992	0.0
993	0.0

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
994	0.0						
995	0.0						
996	0.0						
997	0.0						
998	0.0						
999	0.0						
1000	0.0						
1001	0.0						
1002	0.0						
1003	0.0						
1004	0.0						
1005	0.0						
1006	0.0						
1007	0.0						
1008	0.0						
1009	0.0						
1010	0.0						
1011	0.0						
1012	0.0						
1013	0.0						
1014	0.0						
1015	0.0						
1016	0.0						
1017	0.0						
1018	0.0						
1019	0.0						
1020	0.0						
1021	0.0						
1022	0.0						

Table A1/9

WLTC, Class 3 vehicles, phase Medium$_{3-2}$

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
590	0.0	637	53.0	684	18.9	731	41.9
591	0.0	638	53.0	685	18.9	732	42.0
592	0.0	639	52.9	686	21.3	733	42.2
593	0.0	640	52.7	687	23.9	734	42.4
594	0.0	641	52.6	688	25.9	735	42.7
595	0.0	642	53.1	689	28.4	736	43.1
596	0.0	643	54.3	690	30.3	737	43.7
597	0.0	644	55.2	691	30.9	738	44.0
598	0.0	645	55.5	692	31.1	739	44.1
599	0.0	646	55.9	693	31.8	740	45.3
600	0.0	647	56.3	694	32.7	741	46.4
601	1.0	648	56.7	695	33.2	742	47.2
602	2.1	649	56.9	696	32.4	743	47.3
603	4.8	650	56.8	697	28.3	744	47.4
604	9.1	651	56.0	698	25.8	745	47.4
605	14.2	652	54.2	699	23.1	746	47.5

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
606	19.8	653	52.1	700	21.8	747	47.9
607	25.5	654	50.1	701	21.2	748	48.6
608	30.5	655	47.2	702	21.0	749	49.4
609	34.8	656	43.2	703	21.0	750	49.8
610	38.8	657	39.2	704	20.9	751	49.8
611	42.9	658	36.5	705	19.9	752	49.7
612	46.4	659	34.3	706	17.9	753	49.3
613	48.3	660	31.0	707	15.1	754	48.5
614	48.7	661	26.0	708	12.8	755	47.6
615	48.5	662	20.7	709	12.0	756	46.3
616	48.4	663	15.4	710	13.2	757	43.7
617	48.2	664	13.1	711	17.1	758	39.3
618	47.8	665	12.0	712	21.1	759	34.1
619	47.0	666	12.5	713	21.8	760	29.0
620	45.9	667	14.0	714	21.2	761	23.7
621	44.9	668	19.0	715	18.5	762	18.4
622	44.4	669	23.2	716	13.9	763	14.3
623	44.3	670	28.0	717	12.0	764	12.0
624	44.5	671	32.0	718	12.0	765	12.8
625	45.1	672	34.0	719	13.0	766	16.0
626	45.7	673	36.0	720	16.0	767	19.1
627	46.0	674	38.0	721	18.5	768	22.4
628	46.0	675	40.0	722	20.6	769	25.6
629	46.0	676	40.3	723	22.5	770	30.1
630	46.1	677	40.5	724	24.0	771	35.3
631	46.7	678	39.0	725	26.6	772	39.9
632	47.7	679	35.7	726	29.9	773	44.5
633	48.9	680	31.8	727	34.8	774	47.5
634	50.3	681	27.1	728	37.8	775	50.9
635	51.6	682	22.8	729	40.2	776	54.1
636	52.6	683	21.1	730	41.6	777	56.3
778	58.1	827	37.1	876	72.7	925	64.1
779	59.8	828	38.9	877	71.3	926	62.7
780	61.1	829	41.4	878	70.4	927	62.0
781	62.1	830	44.0	879	70.0	928	61.3
782	62.8	831	46.3	880	70.0	929	60.9
783	63.3	832	47.7	881	69.0	930	60.5
784	63.6	833	48.2	882	68.0	931	60.2
785	64.0	834	48.7	883	68.0	932	59.8
786	64.7	835	49.3	884	68.0	933	59.4
787	65.2	836	49.8	885	68.1	934	58.6
788	65.3	837	50.2	886	68.4	935	57.5
789	65.3	838	50.9	887	68.6	936	56.6
790	65.4	839	51.8	888	68.7	937	56.0
791	65.7	840	52.5	889	68.5	938	55.5
792	66.0	841	53.3	890	68.1	939	55.0
793	65.6	842	54.5	891	67.3	940	54.4
794	63.5	843	55.7	892	66.2	941	54.1

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
795	59.7	844	56.5	893	64.8	942	54.0
796	54.6	845	56.8	894	63.6	943	53.9
797	49.3	846	57.0	895	62.6	944	53.9
798	44.9	847	57.2	896	62.1	945	54.0
799	42.3	848	57.7	897	61.9	946	54.2
800	41.4	849	58.7	898	61.9	947	55.0
801	41.3	850	60.1	899	61.8	948	55.8
802	42.1	851	61.1	900	61.5	949	56.2
803	44.7	852	61.7	901	60.9	950	56.1
804	48.4	853	62.3	902	59.7	951	55.1
805	51.4	854	62.9	903	54.6	952	52.7
806	52.7	855	63.3	904	49.3	953	48.4
807	53.0	856	63.4	905	44.9	954	43.1
808	52.5	857	63.5	906	42.3	955	37.8
809	51.3	858	64.5	907	41.4	956	32.5
810	49.7	859	65.8	908	41.3	957	27.2
811	47.4	860	66.8	909	42.1	958	25.1
812	43.7	861	67.4	910	44.7	959	26.0
813	39.7	862	68.8	911	48.4	960	29.3
814	35.5	863	71.1	912	51.4	961	34.6
815	31.1	864	72.3	913	52.7	962	40.4
816	26.3	865	72.8	914	54.0	963	45.3
817	21.9	866	73.4	915	57.0	964	49.0
818	18.0	867	74.6	916	58.1	965	51.1
819	17.0	868	76.0	917	59.2	966	52.1
820	18.0	869	76.6	918	59.0	967	52.2
821	21.4	870	76.5	919	59.1	968	52.1
822	24.8	871	76.2	920	59.5	969	51.7
823	27.9	872	75.8	921	60.5	970	50.9
824	30.8	873	75.4	922	62.3	971	49.2
825	33.0	874	74.8	923	63.9	972	45.9
826	35.1	875	73.9	924	65.1	973	40.6
974	35.3						
975	30.0						
976	24.7						
977	19.3						
978	16.0						
979	13.2						
980	10.7						
981	8.8						
982	7.2						
983	5.5						
984	3.2						
985	1.1						
986	0.0						
987	0.0						
988	0.0						
989	0.0						
990	0.0						

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
991	0.0						
992	0.0						
993	0.0						
994	0.0						
995	0.0						
996	0.0						
997	0.0						
998	0.0						
999	0.0						
1000	0.0						
1001	0.0						
1002	0.0						
1003	0.0						
1004	0.0						
1005	0.0						
1006	0.0						
1007	0.0						
1008	0.0						
1009	0.0						
1010	0.0						
1011	0.0						
1012	0.0						
1013	0.0						
1014	0.0						
1015	0.0						
1016	0.0						
1017	0.0						
1018	0.0						
1019	0.0						
1020	0.0						
1021	0.0						
1022	0.0						

Table A1/10

WLTC, Class 3 vehicles, phase High$_{3-1}$

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1023	0.0	1070	29.0	1117	66.2	1164	52.6
1024	0.0	1071	32.0	1118	65.8	1165	54.5
1025	0.0	1072	34.8	1119	64.7	1166	56.6
1026	0.0	1073	37.7	1120	63.6	1167	58.3
1027	0.8	1074	40.8	1121	62.9	1168	60.0
1028	3.6	1075	43.2	1122	62.4	1169	61.5
1029	8.6	1076	46.0	1123	61.7	1170	63.1
1030	14.6	1077	48.0	1124	60.1	1171	64.3
1031	20.0	1078	50.7	1125	57.3	1172	65.7
1032	24.4	1079	52.0	1126	55.8	1173	67.1
1033	28.2	1080	54.5	1127	50.5	1174	68.3
1034	31.7	1081	55.9	1128	45.2	1175	69.7

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1035	35.0	1082	57.4	1129	40.1	1176	70.6
1036	37.6	1083	58.1	1130	36.2	1177	71.6
1037	39.7	1084	58.4	1131	32.9	1178	72.6
1038	41.5	1085	58.8	1132	29.8	1179	73.5
1039	43.6	1086	58.8	1133	26.6	1180	74.2
1040	46.0	1087	58.6	1134	23.0	1181	74.9
1041	48.4	1088	58.7	1135	19.4	1182	75.6
1042	50.5	1089	58.8	1136	16.3	1183	76.3
1043	51.9	1090	58.8	1137	14.6	1184	77.1
1044	52.6	1091	58.8	1138	14.2	1185	77.9
1045	52.8	1092	59.1	1139	14.3	1186	78.5
1046	52.9	1093	60.1	1140	14.6	1187	79.0
1047	53.1	1094	61.7	1141	15.1	1188	79.7
1048	53.3	1095	63.0	1142	16.4	1189	80.3
1049	53.1	1096	63.7	1143	19.1	1190	81.0
1050	52.3	1097	63.9	1144	22.5	1191	81.6
1051	50.7	1098	63.5	1145	24.4	1192	82.4
1052	48.8	1099	62.3	1146	24.8	1193	82.9
1053	46.5	1100	60.3	1147	22.7	1194	83.4
1054	43.8	1101	58.9	1148	17.4	1195	83.8
1055	40.3	1102	58.4	1149	13.8	1196	84.2
1056	36.0	1103	58.8	1150	12.0	1197	84.7
1057	30.7	1104	60.2	1151	12.0	1198	85.2
1058	25.4	1105	62.3	1152	12.0	1199	85.6
1059	21.0	1106	63.9	1153	13.9	1200	86.3
1060	16.7	1107	64.5	1154	17.7	1201	86.8
1061	13.4	1108	64.4	1155	22.8	1202	87.4
1062	12.0	1109	63.5	1156	27.3	1203	88.0
1063	12.1	1110	62.0	1157	31.2	1204	88.3
1064	12.8	1111	61.2	1158	35.2	1205	88.7
1065	15.6	1112	61.3	1159	39.4	1206	89.0
1066	19.9	1113	61.7	1160	42.5	1207	89.3
1067	23.4	1114	62.0	1161	45.4	1208	89.8
1068	24.6	1115	64.6	1162	48.2	1209	90.2
1069	27.0	1116	66.0	1163	50.3	1210	90.6
1211	91.0	1260	95.7	1309	75.9	1358	68.2
1212	91.3	1261	95.5	1310	76.0	1359	66.1
1213	91.6	1262	95.3	1311	76.0	1360	63.8
1214	91.9	1263	95.2	1312	76.1	1361	61.6
1215	92.2	1264	95.0	1313	76.3	1362	60.2
1216	92.8	1265	94.9	1314	76.5	1363	59.8
1217	93.1	1266	94.7	1315	76.6	1364	60.4
1218	93.3	1267	94.5	1316	76.8	1365	61.8
1219	93.5	1268	94.4	1317	77.1	1366	62.6
1220	93.7	1269	94.4	1318	77.1	1367	62.7
1221	93.9	1270	94.3	1319	77.2	1368	61.9
1222	94.0	1271	94.3	1320	77.2	1369	60.0
1223	94.1	1272	94.1	1321	77.6	1370	58.4
1224	94.3	1273	93.9	1322	78.0	1371	57.8

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1225	94.4	1274	93.4	1323	78.4	1372	57.8
1226	94.6	1275	92.8	1324	78.8	1373	57.8
1227	94.7	1276	92.0	1325	79.2	1374	57.3
1228	94.8	1277	91.3	1326	80.3	1375	56.2
1229	95.0	1278	90.6	1327	80.8	1376	54.3
1230	95.1	1279	90.0	1328	81.0	1377	50.8
1231	95.3	1280	89.3	1329	81.0	1378	45.5
1232	95.4	1281	88.7	1330	81.0	1379	40.2
1233	95.6	1282	88.1	1331	81.0	1380	34.9
1234	95.7	1283	87.4	1332	81.0	1381	29.6
1235	95.8	1284	86.7	1333	80.9	1382	28.7
1236	96.0	1285	86.0	1334	80.6	1383	29.3
1237	96.1	1286	85.3	1335	80.3	1384	30.5
1238	96.3	1287	84.7	1336	80.0	1385	31.7
1239	96.4	1288	84.1	1337	79.9	1386	32.9
1240	96.6	1289	83.5	1338	79.8	1387	35.0
1241	96.8	1290	82.9	1339	79.8	1388	38.0
1242	97.0	1291	82.3	1340	79.8	1389	40.5
1243	97.2	1292	81.7	1341	79.9	1390	42.7
1244	97.3	1293	81.1	1342	80.0	1391	45.8
1245	97.4	1294	80.5	1343	80.4	1392	47.5
1246	97.4	1295	79.9	1344	80.8	1393	48.9
1247	97.4	1296	79.4	1345	81.2	1394	49.4
1248	97.4	1297	79.1	1346	81.5	1395	49.4
1249	97.3	1298	78.8	1347	81.6	1396	49.2
1250	97.3	1299	78.5	1348	81.6	1397	48.7
1251	97.3	1300	78.2	1349	81.4	1398	47.9
1252	97.3	1301	77.9	1350	80.7	1399	46.9
1253	97.2	1302	77.6	1351	79.6	1400	45.6
1254	97.1	1303	77.3	1352	78.2	1401	44.2
1255	97.0	1304	77.0	1353	76.8	1402	42.7
1256	96.9	1305	76.7	1354	75.3	1403	40.7
1257	96.7	1306	76.0	1355	73.8	1404	37.1
1258	96.4	1307	76.0	1356	72.1	1405	33.9
1259	96.1	1308	76.0	1357	70.2	1406	30.6
1407	28.6	1456	0.0				
1408	27.3	1457	0.0				
1409	27.2	1458	0.0				
1410	27.5	1459	0.0				
1411	27.4	1460	0.0				
1412	27.1	1461	0.0				
1413	26.7	1462	0.0				
1414	26.8	1463	0.0				
1415	28.2	1464	0.0				
1416	31.1	1465	0.0				
1417	34.8	1466	0.0				
1418	38.4	1467	0.0				
1419	40.9	1468	0.0				

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1420	41.7	1469	0.0				
1421	40.9	1470	0.0				
1422	38.3	1471	0.0				
1423	35.3	1472	0.0				
1424	34.3	1473	0.0				
1425	34.6	1474	0.0				
1426	36.3	1475	0.0				
1427	39.5	1476	0.0				
1428	41.8	1477	0.0				
1429	42.5						
1430	41.9						
1431	40.1						
1432	36.6						
1433	31.3						
1434	26.0						
1435	20.6						
1436	19.1						
1437	19.7						
1438	21.1						
1439	22.0						
1440	22.1						
1441	21.4						
1442	19.6						
1443	18.3						
1444	18.0						
1445	18.3						
1446	18.5						
1447	17.9						
1448	15.0						
1449	9.9						
1450	4.6						
1451	1.2						
1452	0.0						
1453	0.0						
1454	0.0						
1455	0.0						

Table A1/11

WLTC, Class 3 vehicles, phase High$_{3-2}$

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1023	0.0	1070	26.4	1117	69.7	1164	52.6
1024	0.0	1071	28.8	1118	69.3	1165	54.5
1025	0.0	1072	31.8	1119	68.1	1166	56.6
1026	0.0	1073	35.3	1120	66.9	1167	58.3
1027	0.8	1074	39.5	1121	66.2	1168	60.0
1028	3.6	1075	44.5	1122	65.7	1169	61.5
1029	8.6	1076	49.3	1123	64.9	1170	63.1
1030	14.6	1077	53.3	1124	63.2	1171	64.3
1031	20.0	1078	56.4	1125	60.3	1172	65.7

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1032	24.4	1079	58.9	1126	55.8	1173	67.1
1033	28.2	1080	61.2	1127	50.5	1174	68.3
1034	31.7	1081	62.6	1128	45.2	1175	69.7
1035	35.0	1082	63.0	1129	40.1	1176	70.6
1036	37.6	1083	62.5	1130	36.2	1177	71.6
1037	39.7	1084	60.9	1131	32.9	1178	72.6
1038	41.5	1085	59.3	1132	29.8	1179	73.5
1039	43.6	1086	58.6	1133	26.6	1180	74.2
1040	46.0	1087	58.6	1134	23.0	1181	74.9
1041	48.4	1088	58.7	1135	19.4	1182	75.6
1042	50.5	1089	58.8	1136	16.3	1183	76.3
1043	51.9	1090	58.8	1137	14.6	1184	77.1
1044	52.6	1091	58.8	1138	14.2	1185	77.9
1045	52.8	1092	59.1	1139	14.3	1186	78.5
1046	52.9	1093	60.1	1140	14.6	1187	79.0
1047	53.1	1094	61.7	1141	15.1	1188	79.7
1048	53.3	1095	63.0	1142	16.4	1189	80.3
1049	53.1	1096	63.7	1143	19.1	1190	81.0
1050	52.3	1097	63.9	1144	22.5	1191	81.6
1051	50.7	1098	63.5	1145	24.4	1192	82.4
1052	48.8	1099	62.3	1146	24.8	1193	82.9
1053	46.5	1100	60.3	1147	22.7	1194	83.4
1054	43.8	1101	58.9	1148	17.4	1195	83.8
1055	40.3	1102	58.4	1149	13.8	1196	84.2
1056	36.0	1103	58.8	1150	12.0	1197	84.7
1057	30.7	1104	60.2	1151	12.0	1198	85.2
1058	25.4	1105	62.3	1152	12.0	1199	85.6
1059	21.0	1106	63.9	1153	13.9	1200	86.3
1060	16.7	1107	64.5	1154	17.7	1201	86.8
1061	13.4	1108	64.4	1155	22.8	1202	87.4
1062	12.0	1109	63.5	1156	27.3	1203	88.0
1063	12.1	1110	62.0	1157	31.2	1204	88.3
1064	12.8	1111	61.2	1158	35.2	1205	88.7
1065	15.6	1112	61.3	1159	39.4	1206	89.0
1066	19.9	1113	62.6	1160	42.5	1207	89.3
1067	23.4	1114	65.3	1161	45.4	1208	89.8
1068	24.6	1115	68.0	1162	48.2	1209	90.2
1069	25.2	1116	69.4	1163	50.3	1210	90.6
1211	91.0	1260	95.7	1309	75.9	1358	68.2
1212	91.3	1261	95.5	1310	75.9	1359	66.1
1213	91.6	1262	95.3	1311	75.8	1360	63.8
1214	91.9	1263	95.2	1312	75.7	1361	61.6
1215	92.2	1264	95.0	1313	75.5	1362	60.2
1216	92.8	1265	94.9	1314	75.2	1363	59.8
1217	93.1	1266	94.7	1315	75.0	1364	60.4
1218	93.3	1267	94.5	1316	74.7	1365	61.8
1219	93.5	1268	94.4	1317	74.1	1366	62.6
1220	93.7	1269	94.4	1318	73.7	1367	62.7

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1221	93.9	1270	94.3	1319	73.3	1368	61.9
1222	94.0	1271	94.3	1320	73.5	1369	60.0
1223	94.1	1272	94.1	1321	74.0	1370	58.4
1224	94.3	1273	93.9	1322	74.9	1371	57.8
1225	94.4	1274	93.4	1323	76.1	1372	57.8
1226	94.6	1275	92.8	1324	77.7	1373	57.8
1227	94.7	1276	92.0	1325	79.2	1374	57.3
1228	94.8	1277	91.3	1326	80.3	1375	56.2
1229	95.0	1278	90.6	1327	80.8	1376	54.3
1230	95.1	1279	90.0	1328	81.0	1377	50.8
1231	95.3	1280	89.3	1329	81.0	1378	45.5
1232	95.4	1281	88.7	1330	81.0	1379	40.2
1233	95.6	1282	88.1	1331	81.0	1380	34.9
1234	95.7	1283	87.4	1332	81.0	1381	29.6
1235	95.8	1284	86.7	1333	80.9	1382	27.3
1236	96.0	1285	86.0	1334	80.6	1383	29.3
1237	96.1	1286	85.3	1335	80.3	1384	32.9
1238	96.3	1287	84.7	1336	80.0	1385	35.6
1239	96.4	1288	84.1	1337	79.9	1386	36.7
1240	96.6	1289	83.5	1338	79.8	1387	37.6
1241	96.8	1290	82.9	1339	79.8	1388	39.4
1242	97.0	1291	82.3	1340	79.8	1389	42.5
1243	97.2	1292	81.7	1341	79.9	1390	46.5
1244	97.3	1293	81.1	1342	80.0	1391	50.2
1245	97.4	1294	80.5	1343	80.4	1392	52.8
1246	97.4	1295	79.9	1344	80.8	1393	54.3
1247	97.4	1296	79.4	1345	81.2	1394	54.9
1248	97.4	1297	79.1	1346	81.5	1395	54.9
1249	97.3	1298	78.8	1347	81.6	1396	54.7
1250	97.3	1299	78.5	1348	81.6	1397	54.1
1251	97.3	1300	78.2	1349	81.4	1398	53.2
1252	97.3	1301	77.9	1350	80.7	1399	52.1
1253	97.2	1302	77.6	1351	79.6	1400	50.7
1254	97.1	1303	77.3	1352	78.2	1401	49.1
1255	97.0	1304	77.0	1353	76.8	1402	47.4
1256	96.9	1305	76.7	1354	75.3	1403	45.2
1257	96.7	1306	76.0	1355	73.8	1404	41.8
1258	96.4	1307	76.0	1356	72.1	1405	36.5
1259	96.1	1308	76.0	1357	70.2	1406	31.2
1407	27.6	1456	0.0				
1408	26.9	1457	0.0				
1409	27.3	1458	0.0				
1410	27.5	1459	0.0				
1411	27.4	1460	0.0				
1412	27.1	1461	0.0				
1413	26.7	1462	0.0				
1414	26.8	1463	0.0				
1415	28.2	1464	0.0				
1416	31.1	1465	0.0				

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1417	34.8	1466	0.0				
1418	38.4	1467	0.0				
1419	40.9	1468	0.0				
1420	41.7	1469	0.0				
1421	40.9	1470	0.0				
1422	38.3	1471	0.0				
1423	35.3	1472	0.0				
1424	34.3	1473	0.0				
1425	34.6	1474	0.0				
1426	36.3	1475	0.0				
1427	39.5	1476	0.0				
1428	41.8	1477	0.0				
1429	42.5						
1430	41.9						
1431	40.1						
1432	36.6						
1433	31.3						
1434	26.0						
1435	20.6						
1436	19.1						
1437	19.7						
1438	21.1						
1439	22.0						
1440	22.1						
1441	21.4						
1442	19.6						
1443	18.3						
1444	18.0						
1445	18.3						
1446	18.5						
1447	17.9						
1448	15.0						
1449	9.9						
1450	4.6						
1451	1.2						
1452	0.0						
1453	0.0						
1454	0.0						
1455	0.0						

Table A1/12

WLTC, Class 3 vehicles, phase Extra High$_3$

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Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1478	0.0	1525	72.5	1572	120.7	1619	113.0
1479	2.2	1526	70.8	1573	121.8	1620	114.1
1480	4.4	1527	68.6	1574	122.6	1621	115.1
1481	6.3	1528	66.2	1575	123.2	1622	115.9
1482	7.9	1529	64.0	1576	123.6	1623	116.5

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1483	9.2	1530	62.2	1577	123.7	1624	116.7
1484	10.4	1531	60.9	1578	123.6	1625	116.6
1485	11.5	1532	60.2	1579	123.3	1626	116.2
1486	12.9	1533	60.0	1580	123.0	1627	115.2
1487	14.7	1534	60.4	1581	122.5	1628	113.8
1488	17.0	1535	61.4	1582	122.1	1629	112.0
1489	19.8	1536	63.2	1583	121.5	1630	110.1
1490	23.1	1537	65.6	1584	120.8	1631	108.3
1491	26.7	1538	68.4	1585	120.0	1632	107.0
1492	30.5	1539	71.6	1586	119.1	1633	106.1
1493	34.1	1540	74.9	1587	118.1	1634	105.8
1494	37.5	1541	78.4	1588	117.1	1635	105.7
1495	40.6	1542	81.8	1589	116.2	1636	105.7
1496	43.3	1543	84.9	1590	115.5	1637	105.6
1497	45.7	1544	87.4	1591	114.9	1638	105.3
1498	47.7	1545	89.0	1592	114.5	1639	104.9
1499	49.3	1546	90.0	1593	114.1	1640	104.4
1500	50.5	1547	90.6	1594	113.9	1641	104.0
1501	51.3	1548	91.0	1595	113.7	1642	103.8
1502	52.1	1549	91.5	1596	113.3	1643	103.9
1503	52.7	1550	92.0	1597	112.9	1644	104.4
1504	53.4	1551	92.7	1598	112.2	1645	105.1
1505	54.0	1552	93.4	1599	111.4	1646	106.1
1506	54.5	1553	94.2	1600	110.5	1647	107.2
1507	55.0	1554	94.9	1601	109.5	1648	108.5
1508	55.6	1555	95.7	1602	108.5	1649	109.9
1509	56.3	1556	96.6	1603	107.7	1650	111.3
1510	57.2	1557	97.7	1604	107.1	1651	112.7
1511	58.5	1558	98.9	1605	106.6	1652	113.9
1512	60.2	1559	100.4	1606	106.4	1653	115.0
1513	62.3	1560	102.0	1607	106.2	1654	116.0
1514	64.7	1561	103.6	1608	106.2	1655	116.8
1515	67.1	1562	105.2	1609	106.2	1656	117.6
1516	69.2	1563	106.8	1610	106.4	1657	118.4
1517	70.7	1564	108.5	1611	106.5	1658	119.2
1518	71.9	1565	110.2	1612	106.8	1659	120.0
1519	72.7	1566	111.9	1613	107.2	1660	120.8
1520	73.4	1567	113.7	1614	107.8	1661	121.6
1521	73.8	1568	115.3	1615	108.5	1662	122.3
1522	74.1	1569	116.8	1616	109.4	1663	123.1
1523	74.0	1570	118.2	1617	110.5	1664	123.8
1524	73.6	1571	119.5	1618	111.7	1665	124.4
1666	125.0	1715	127.7	1764	82.0		
1667	125.4	1716	128.1	1765	81.3		
1668	125.8	1717	128.5	1766	80.4		
1669	126.1	1718	129.0	1767	79.1		
1670	126.4	1719	129.5	1768	77.4		
1671	126.6	1720	130.1	1769	75.1		
1672	126.7	1721	130.6	1770	72.3		

Time in s	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*	*Time in s*	*speed in km/h*
1673	126.8	1722	131.0	1771	69.1		
1674	126.9	1723	131.2	1772	65.9		
1675	126.9	1724	131.3	1773	62.7		
1676	126.9	1725	131.2	1774	59.7		
1677	126.8	1726	130.7	1775	57.0		
1678	126.6	1727	129.8	1776	54.6		
1679	126.3	1728	128.4	1777	52.2		
1680	126.0	1729	126.5	1778	49.7		
1681	125.7	1730	124.1	1779	46.8		
1682	125.6	1731	121.6	1780	43.5		
1683	125.6	1732	119.0	1781	39.9		
1684	125.8	1733	116.5	1782	36.4		
1685	126.2	1734	114.1	1783	33.2		
1686	126.6	1735	111.8	1784	30.5		
1687	127.0	1736	109.5	1785	28.3		
1688	127.4	1737	107.1	1786	26.3		
1689	127.6	1738	104.8	1787	24.4		
1690	127.8	1739	102.5	1788	22.5		
1691	127.9	1740	100.4	1789	20.5		
1692	128.0	1741	98.6	1790	18.2		
1693	128.1	1742	97.2	1791	15.5		
1694	128.2	1743	95.9	1792	12.3		
1695	128.3	1744	94.8	1793	8.7		
1696	128.4	1745	93.8	1794	5.2		
1697	128.5	1746	92.8	1795	0.0		
1698	128.6	1747	91.8	1796	0.0		
1699	128.6	1748	91.0	1797	0.0		
1700	128.5	1749	90.2	1798	0.0		
1701	128.3	1750	89.6	1799	0.0		
1702	128.1	1751	89.1	1800	0.0		
1703	127.9	1752	88.6				
1704	127.6	1753	88.1				
1705	127.4	1754	87.6				
1706	127.2	1755	87.1				
1707	127.0	1756	86.6				
1708	126.9	1757	86.1				
1709	126.8	1758	85.5				
1710	126.7	1759	85.0				
1711	126.8	1760	84.4				
1712	126.9	1761	83.8				
1713	127.1	1762	83.2				
1714	127.4	1763	82.6				

7. Cycle modification

7.1. General remarks

The cycle to be driven shall depend on the test vehicle’s rated power to unladen mass ratio, W/kg, and its maximum velocity, v_{max}.

Driveability problems may occur for vehicles with power to mass ratios close to the borderlines between Class 2 and Class 3 vehicles or very low powered vehicles in Class 1.

Since these problems are related mainly to cycle phases with a combination of high vehicle speed and high accelerations rather than to the maximum speed of the cycle, the downscaling procedure shall be applied to improve driveability.

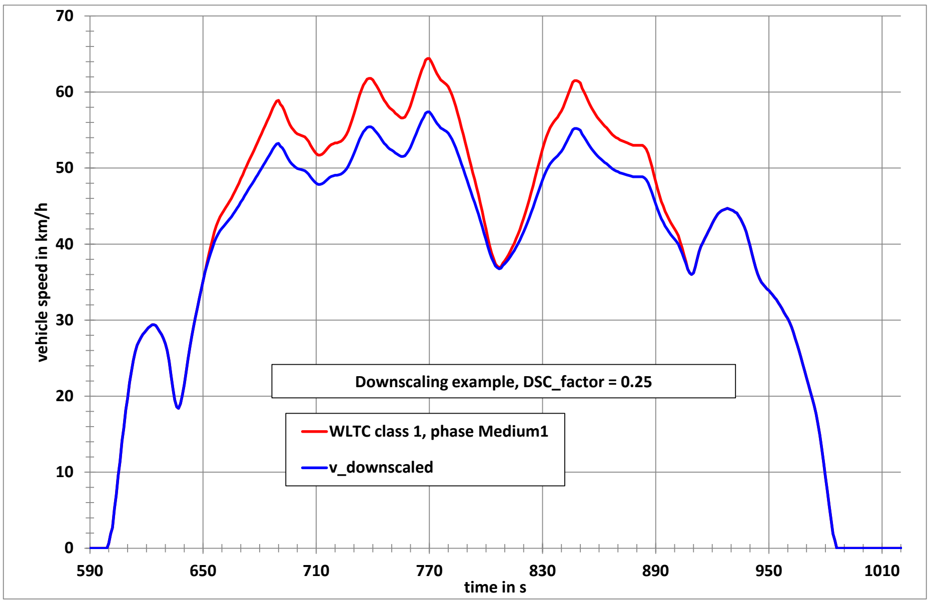
This paragraph shall not apply to vehicles tested according to Sub-Annex 8.

7.2. This paragraph describes the method to modify the cycle profile using the downscaling procedure.

7.2.1. Downscaling procedure for Class 1 vehicles

Figure A1/13 shows an example for a downscaled medium speed phase of the Class 1 WLTC.

Figure A1/13
Downscaled medium speed phase of the Class 1 WLTC



For the Class 1 cycle, the downscaling period is the time period between second 651 and second 906. Within this time period, the acceleration for the original cycle shall be calculated using the following equation:

$$a_{orig_i} = \frac{v_{i+1} - v_i}{3.6} \qquad (1)$$

where:

v_i is the vehicle speed, km/h;

i is the time between second 651 and second 906.

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The downscaling shall be first applied in the time period between second 651 and second 848. The downscaled speed trace shall then be calculated using the following equation:

$$v_{dsc_{i+1}} = v_{dsc_i} + a_{orig_i} \times (1 - dsc\_factor) \times 3.6 \qquad (2)$$

with i = 651 to 847.

For i = 651, $v_{dsc_i} = v_{orig_i}$. (3)

In order to meet the original vehicle speed at second 907, a correction factor for the deceleration shall be calculated using the following equation:

$$f_{corr\_dec} = \frac{v_{dsc\_848} - 36.7}{v_{orig\_848} - 36.7} \qquad (4)$$

where 36.7 km/h is the original vehicle speed at second 907.

The downscaled vehicle speed between second 849 and second 906 shall then be calculated using the following equation:

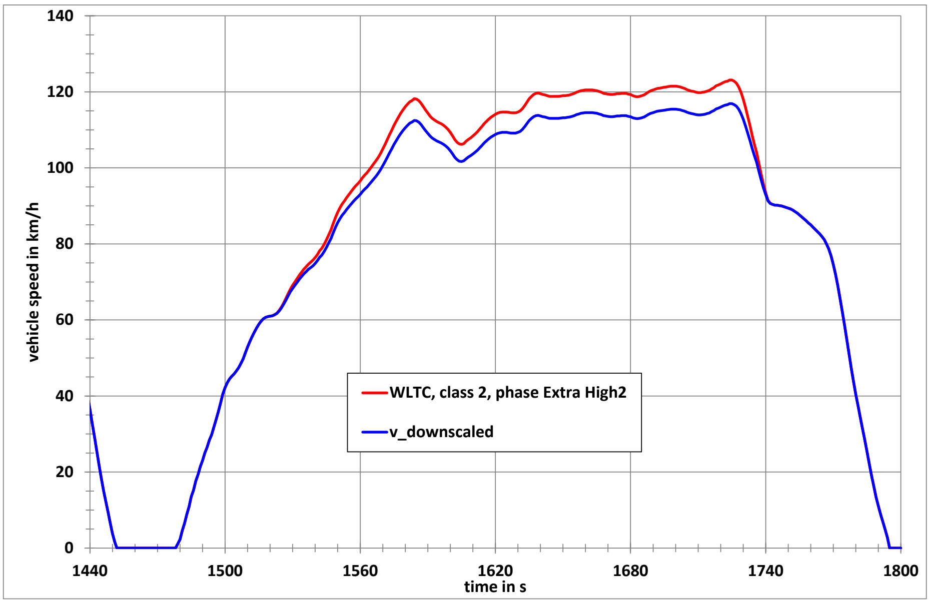
$$v_{dsc_i} = v_{dsc_{i-1}} + a_{orig_{i-1}} \times f_{corr\_dec} \times 3.6 \qquad (5)$$

with i = 849 to 906.

7.2.2. Downscaling procedure for Class 2 vehicles

Since the driveability problems are exclusively related to the extra high speed phases of the Class 2 and Class 3 cycles, the downscaling is related to those paragraphs of the extra high speed phases where the driveability problems occur (see Figure A1/14).

Figure A1/14
Downscaled extra high speed phase of the Class 2 WLTC



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For the Class 2 cycle, the downscaling period is the time period between second 1520 and second 1742. Within this time period, the acceleration for the original cycle shall be calculated using the following equation:

$$a_{orig_i} = \frac{v_{i+1} - v_i}{3.6} \quad (6)$$

where:

v_i is the vehicle speed, km/h;

i is the time between second 1520 and second 1742.

The downscaling shall be applied first in the time period between second 1520 and second 1725. Second 1725 is the time where the maximum speed of the extra high speed phase is reached. The downscaled speed trace shall then be calculated using the following equation:

$$v_{dsc_{i+1}} = v_{dsc_i} + a_{orig_i} \times (1 - dsc\_factor) \times 3.6 \quad (7)$$

with i = 1520 to 1724 .

For i = 1520, $v_{dsc_i} = v_{orig_i}$. (8)

In order to meet the original vehicle speed at second 1743, a correction factor for the deceleration shall be calculated using the following equation:

$$f_{corr\_dec} = \frac{v_{dsc\_1725} - 90.4}{v_{orig\_1725} - 90.4} \quad (9)$$

90.4 km/h is the original vehicle speed at second 1743.

The downscaled vehicle speed between second 1726 and second 1742 shall be calculated using the following equation:

$$v_{dsc_i} = v_{dsc_{i-1}} + a_{orig_{i-1}} \times f_{corr\_dec} \times 3.6 \quad (10)$$

with i = 1726 to 1742.

7.2.3. Downscaling procedure for Class 3 vehicles

Figure A1/15 shows an example for a downscaled extra high speed phase of the Class 3 WLTC.

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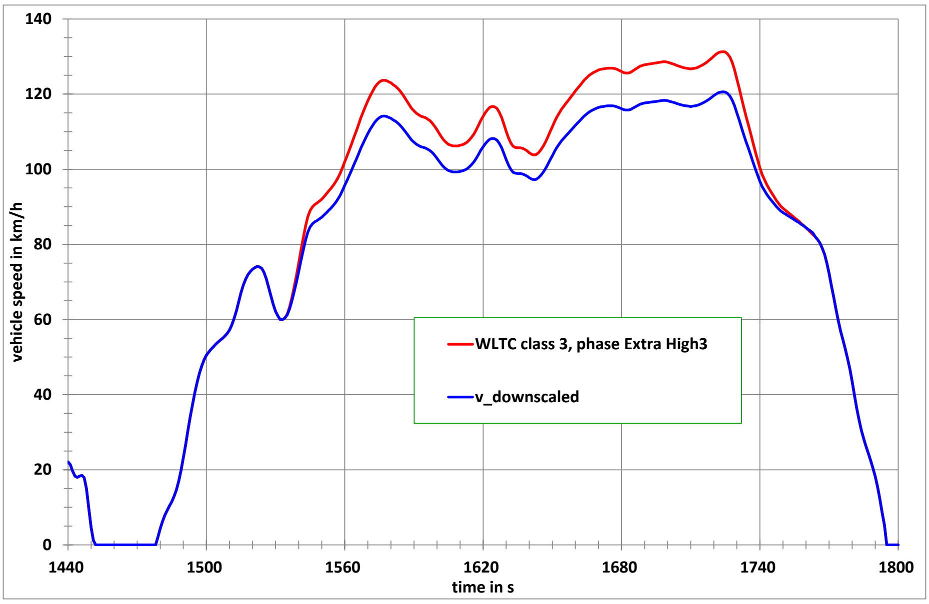
Figure A1/15
Downscaled extra high speed phase of the Class 3 WLTC



For the Class 3 cycle, this is the period between second 1533 and second 1762. Within this time period, the acceleration for the original cycle shall be calculated using the following equation:

$$a_{orig_i} = \frac{v_{i+1} - v_i}{3.6} \quad (11)$$

where:

v_i is the vehicle speed, km/h;

i is the time between second 1533 and second 1762.

The downscaling shall be applied first in the time period between second 1533 and second 1724. Second 1724 is the time where the maximum speed of the extra high speed phase is reached. The downscaled speed trace shall then be calculated using the following equation:

$$v_{dsc_{i+1}} = v_{dsc_i} + a_{orig_i} \times (1 - dsc\_factor) \times 3.6 \quad (12)$$

with i = 1533 to 1723.

For i = 1533, $v_{dsc_i} = v_{orig_i}$. (13)

In order to meet the original vehicle speed at second 1763, a correction factor for the deceleration is calculated using the following equation:

$$f_{corr\_dec} = \frac{v_{dsc\_1724} - 82.6}{v_{orig\_1724} - 82.6} \quad (14)$$

82.6 km/h is the original vehicle speed at second 1763.

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The downscaled vehicle speed between second 1725 and second 1762 shall then be calculated using the following equation:

$$v_{dsc_i} = v_{dsc_{i-1}} + a_{orig_{i-1}} \times f_{corr\_dec} \times 3.6 \quad (15)$$

with $i = 1725$ to 1762.

7.3. Determination of the downscaling factor

The downscaling factor f_{dsc} is a function of the ratio, r_{max}, between the maximum required power of the cycle phases where the downscaling is to be applied and the rated power of the vehicle (P_{rated}).

The maximum required power, $P_{req,max,i}$ in kW, is related to a specific time i in the cycle trace and is calculated from the road load coefficients f_0, f_1, f_2 and the test mass TM as follows:

$$P_{req,max,i} = \frac{\left((f_0 \times v_i) + (f_1 \times v_i^2) + (f_2 \times v_i^3) + (1.1 \times TM \times v_i \times a_i)\right)}{3600} \quad (16)$$

with f_0 in N, f_1 in N/(km/h) and f_2 in N/(km/h)^2, TM in kg.

f_0, f_1 and f_2 are the road load coefficients for the test mass TM under consideration and shall be determined by coastdown measurements as described in paragraph 4.3.1.4.5. of Sub-Annex 4 or an equivalent method.

The cycle time i, at which maximum power or power values close to maximum power is required, is: second 764 for Class 1, second 1574 for Class 2 and second 1566 for Class 3 vehicles.

The corresponding vehicle speed values v_i and acceleration values a_i are as follows:

$v_i = 61.4$ km/h, $a_i = 0.22$ m/s² for Class 1,

$v_i = 109.9$ km/h, $a_i = 0.36$ m/s² for Class 2,

$v_i = 111.9$ km/h, $a_i = 0.50$ m/s² for Class 3.

r_{max} is calculated using the following equation:

$$r_{max} = \frac{P_{req,max,i}}{P_{rated}} \quad (17)$$

The downscaling factor f_{dsc} is calculated using the following equations:

if $r_{max} < r_0$, then $f_{dsc} = 0$ (18)

if $r_{max} \geq r_0$, then $f_{dsc} = a_1 \times r_{max} + b_1$ (19)

The calculation parameter/coefficients r_0, a_1 and b_1 are as follows:

Class 1: $r_0 = 1.0$, $a_1 = 0.54$, $b_1 = -0.54$

Class 2: for vehicles with $v_{max} > 105$ km/h, $r_0 = 1.0$, $a_1 = 0.6$, $b_1 = -0.6$. No downscaling shall be applied for vehicles with $v_{max} \leq 105$ km/h

Class 3: for vehicles with $v_{max} > 112$ km/h, $r_0 = 1.0$, $a_1 = 0.65$, $b_1 = -0.65$; for vehicles with $v_{max} \leq 112$ km/h, $r_0 = 1.3$, $a_1 = 0.65$, $b_1 = -0.65$.

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Comment [RCG42]: AdminWG 290414 – agreed to include Heinz Steven's new text

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Comment [RCG43]: X-ref may change to para 4.5.5.1.

NB: this revised paragraph is not in the 20.05.14 GTR

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Comment [RCG44]: Post AdminWG 010414 – Heinz Steven confirmed that the word "second" should be included before the numbers.

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Comment [RCG45]: AdminWG 290414 – agreed to include Heinz Steven's amendment

Deleted: The driving resistance coefficients f_0, f_1 and f_2 shall be determined by coastdown measurements or an equivalent method.

Comment [RCG46]: AdminWG 290414 – now that the paragraph above is deleted do we need to have something to separate this text from the vi values above?

AdminWG 080514 – waiting for feedback from Heinz Steven following his meeting on 8th May.

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The resulting f_{dsc} is mathematically rounded to one decimal place the comma and is only applied if it exceeds one per cent.

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7.4. Additional requirements

If a vehicle is tested under different configurations in terms of test mass and driving resistance coefficients, vehicle L as defined in paragraph 4.2.1. of Sub-Annex 4 shall be used for the determination of the downscaling factor and the resulting downscaled cycle shall be used for all measurements.

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If the maximum speed of the vehicle is lower than the maximum speed of the downscaled cycle, the vehicle shall be driven with its maximum speed in those cycle periods where the cycle speed is higher than the maximum speed of the vehicle.

If the vehicle cannot follow the speed trace of the downscaled cycle within the tolerance for specific periods, it shall be driven with the accelerator control fully activated during these periods. During such periods of operation, driving trace violations shall be permitted.

Sub-Annex 2

Gear selection and shift point determination for vehicles equipped with manual transmissions

1. General approach

1.1. The shifting procedures described in this Sub-Annex shall apply to vehicles equipped with manual and automatic shift transmissions.

1.2. The prescribed gears and shifting points are based on the balance between the power required to overcome driving resistance and acceleration, and the power provided by the engine in all possible gears at a specific cycle phase.

1.3. The calculation to determine the gears to use shall be based on normalised engine speeds (normalised to the span between idling speed and rated engine speed) and normalised full load power curves (normalised to rated power) versus normalised engine speed.

1.4. This Sub-Annex shall not apply to vehicles tested according to Sub-Annex 8.

2. Required data

The following data is required to calculate the gears to be used when driving the cycle on a chassis dynamometer:

(a) P_{rated}, the maximum rated engine power as declared by the manufacturer;

(b) s, the rated engine speed at which an engine develops its maximum power. If the maximum power is developed over an engine speed range, s is determined by the mean of this range;

(c) n_{idle}, idling speed;

(d) ng_{max}, the number of forward gears;

(e) n_{min_drive}, minimum engine speed for gears i > 2 when the vehicle is in motion. The minimum value is determined by the following equation:

$$n_{min\_drive} = n_{idle} + 0.125 \times (s - n_{idle}) \quad (1)$$

Higher values may be used if requested by the manufacturer;

(f) ndv_i, the ratio obtained by dividing n in min^{-1} by v in km/h for each gear i, i = 1 to ng_{max};

(g) TM, test mass of the vehicle in kg;

(h)

f_0, f_1, f_2 in N, N/(km/h), and N/(km/h)² respectively are the road load coefficients for the test mass under consideration and shall be determined by coastdown measurements as described in paragraph 4.3.1.4.5. of Sub-Annex 4 or an equivalent method;

(i)

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Comment [RCG47]: Post AdminWG 010414 – Heinz Steven provided new text for (h).

(h) f_0, f_1, f_2 in N, N/(km/h), and N/(km/h)² respectively are the road load coefficients for the test mass under consideration and shall be determined by coastdown measurements as described in paragraph 4.3.1.4.5. of Sub-Annex 4 or an equivalent method.

Deleted: f_0, f_1, f_2, driving resistance coefficients as defined of Annex 4 in N, N/(km/h), and N/(km/h)² respectively

Comment [RCG48]: May change to para 4.5.5.1.

Comment [RCG49]: AdminWG 010414 – Heinz Steven to look into this.

AdminWG 290414 – agreed to include Heinz Steven's new text

Deleted: $P_{wot}(n_{norm})/P_{rated}$ is the full load power curve, normalised to rated power and (rated engine speed – idling speed), where $n_{norm} = \frac{n - n_{idle}}{s - n_{idle}}$.

$P_{norm\_wot}(n_{norm\,i,j})$ is the full load power curve, normalised to rated power over the engine speed, normalised to (rated engine speed – idling speed), where $(n_{norm} = \frac{n - n_{idle}}{s - n_{idle}})$. (2)

Comment [RCG50]: GTR OPEN POINT: 05.05.2014: This definition will be revised by experts shortly.

3. Calculations of required power, engine speeds, available power, and possible gear to be used

3.1. Calculation of required power

For every second j of the cycle trace, the power required to overcome driving resistance and to accelerate shall be calculated using the following equation:

$$P_{required,j} = \left(\frac{f_0 \times v_j + f_1 \times v_j^2 + f_2 \times v_j^3}{3600}\right) + \frac{kr \times a_j \times v_j \times TM}{3600} \quad (3)$$

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where:

f_0 is the road load coefficient, N;

f_1 is the road load parameter dependent on velocity, N/(km/h);

f_2 is the road load parameter based on the square of velocity, N/(km/h)²;

$P_{required,j}$ is the required power at second j, kW;

v_j is the vehicle speed at second j, km/h;

a_j is the vehicle acceleration at second j, m/s², $a_j = \frac{(v_{j+1} - v_j)}{3.6}$; (4)

TM is the vehicle test mass, kg;

kr is a factor taking the inertial resistances of the drivetrain during acceleration into account and is set to 1.1.

3.2. Determination of engine speeds

For each $v_j \leq 1$ km/h, the engine speed shall be set to n_{idle} and the gear lever shall be placed in neutral with the clutch engaged.

For each $v_j \geq 1$ km/h of the cycle trace and each gear i, $i = 1$ to ng_{max}, the engine speed $n_{i,j}$ shall be calculated using the following equation:

$$n_{i,j} = ndv_i \times v_j \quad (5)$$

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All gears i for which $n_{min} \leq n_{i,j} \leq n_{max}$ are possible gears to be used for driving the cycle trace at v_j.

If $i > 2$,

Deleted: if

$n_{max} = 1.2 \times (s - n_{idle}) + n_{idle}$ (6)

$n_{min} = n_{min\_drive}$; (7)

If $i = 2$ and $ndv_2 \times v_j \geq 0.9 \times n_{idle}$, (8)

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$n_{min} = \max(1.15 \times n_{idle},\ 0.03 \times (s - n_{idle}) + n_{idle})$;

if $ndv_2 \times v_j < \max(1.15 \times n_{idle}, 0.03 \times (s - n_{idle}) + n_{idle})$, the clutch shall be disengaged.

If $i = 1$,

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$$n_{min} = n_{idle} \quad (9)$$

[Deleted: .]

3.3. Calculation of available power

The available power for each possible gear i and each vehicle speed value of the cycle trace v_i shall be calculated using the following equation:

$$P_{available\_i,j} = P_{norm\_wot}(n_{norm\ i,j}) \times P_{rated} \times SM \quad (10)$$

[Deleted: 4]

where:

$$n_{norm_{i,j}} = \frac{(ndv_i) \times v_j - n_{idle}}{s - n_{idle}} \quad (11)$$

and:

P_{rated} is the rated power, kW;

P_{norm_wot} is the percentage of rated power available at $n_{norm\ i,j}$ at full load condition from the normalised full load power curve;

SM is a safety margin accounting for the difference between the stationary full load condition power curve and the power available during transition conditions. SM is set to 0.9;

n_{idle} is the idling speed, min^{-1};

s is the rated engine speed.

3.4. Determination of possible gears to be used

The possible gears to be used shall be determined by the following conditions:

(a) $n_{min} \leq n_{i,j} \leq n_{max}$;

(b) $P_{available\_i,j} \geq P_{required,j}$

The initial gear to be used for each second j of the cycle trace is the highest final possible gear i_max. When starting from standstill, only the first gear shall be used.

4. Additional requirements for corrections and/or modifications of gear use

The initial gear selection shall be checked and modified in order to avoid too frequent gearshifts and to ensure driveability and practicality.

Corrections and/or modifications shall be made according to the following requirements:

(a) First gear shall be selected 1 second before beginning an acceleration phase from standstill with the clutch disengaged. Vehicle speeds below 1 km/h imply that the vehicle is standing still;

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(b) Gears shall not be skipped during acceleration phases. Gears used during accelerations and decelerations must be used for a period of at least 3 seconds (e.g. a gear sequence 1, 1, 2, 2, 3, 3, 3, 3, 3 shall be replaced by 1, 1, 1, 2, 2, 2, 3, 3, 3);

[Deleted: three]

(c) Gears may be skipped during deceleration phases. For the last phase of a deceleration to a stop, the clutch may be either disengaged or the gear lever placed in neutral and the clutch left engaged;

(d) There shall be no gearshift during transition from an acceleration phase to a deceleration phase. E.g., if $v_j < v_{j+1} > v_{j+2}$ and the gear for the time sequence j and $j + 1$ is i, gear i is also kept for the time $j + 2$, even if the initial gear for $j + 2$ would be $i + 1$;

(e) If a gear i is used for a time sequence of 1 to 5 seconds and the gear before this sequence is the same as the gear after this sequence, e.g. $i - 1$, the gear use for this sequence shall be corrected to $i - 1$.

Example:

(i) a gear sequence $i - 1$, i, $i - 1$ is replaced by $i - 1$, $i - 1$, $i - 1$;

(ii) a gear sequence $i - 1$, i, i, $i - 1$ is replaced by $i - 1$, $i - 1$, $i - 1$, $i - 1$;

(iii) a gear sequence $i - 1$, i, i,i, $i - 1$ is replaced by $i - 1$, $i - 1$,$i - 1$, $i - 1$, $i - 1$;

(iv) a gear sequence $i - 1$, i, i, i, i, $i - 1$ is replaced by $i - 1$, $i - 1$, $i - 1$, $i - 1$, $i - 1$, $i - 1$;

(v) a gear sequence $i - 1$, i, i, i, i, i, $i - 1$ is replaced by $i - 1$, $i - 1$, $i - 1$, $i - 1$, $i - 1$, $i - 1$, $i - 1$.

For all cases (i) to (v), $g_{min} \leq i$ must be fulfilled;

(f) A gear sequence i,$i - 1$,i, shall be replaced by i,i,i, if the following conditions are fulfilled:

(i) Engine speed does not drop below n_{min}; and

(ii) The sequence does not occur more often than four times each for the low, medium and high speed cycle phases and not more than three times for the extra high speed phase.

Requirement (ii) is necessary as the available power will drop below the required power when the gear $i - 1$, is replaced by i;

(g) If, during an acceleration phase, a lower gear is required at a higher vehicle speed for at least 2 seconds, the higher gears before shall be corrected to the lower gear.

Example: $v_j < v_{j+1} < v_{j+2} < v_{j+3} < v_{j+4} < v_{j+5} < v_{j+6}$. The originally calculated gear use is 2, 3, 3, 3, 2, 2, 3. In this case the gear use will be corrected to 2, 2, 2, 2, 2, 2, 3.

Since the above modifications may create new gear use sequences which are in conflict with these requirements, the gear sequences shall be checked twice.

[Sub-Annex 3

Reference fuels

[RESERVED. Specifications for Reference Fuels are found in Annex IX]

1. As there are regional differences in the market specifications of fuels, regionally different reference fuels need to be recognised. Example reference fuels are however required in this gtr for the calculation of hydrocarbon emissions and fuel consumption. Reference fuels are therefore given as examples for such illustrative purposes.

2. It is recommended that Contracting Parties select their reference fuels from this Sub Annex and bring any regionally agreed amendments or alternatives into this gtr by amendment. This does not however limit the right of Contracting Parties to define individual reference fuels to reflect local market fuel specifications.

3. Liquid fuels for positive ignition engines

[NB: all reference fuels tables deleted and track-change accepted 4th April 2014]

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Comment [RCG51]: The fuel specifications are included in Annex IX of 692/2008 and are therefore not needed here.

Therefore delete everything and have an empty reserved sub-annex – with a brief explanation why.

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Sub-Annex 4

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Road load and dynamometer setting

1. Scope

This Sub-Annex describes the determination of the road load of a test vehicle and the transfer of that road load to a chassis dynamometer.

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2. Terms and definitions

For the purpose of this document, the terms and definitions given in paragraph 3. of this Annex have primacy. Where definitions are not provided in paragraph 3. the definitions given in ISO 3833:1977 "Road vehicles -- Types -- Terms and definitions" shall apply.

Comment [RCG52]: AdminWG 010414 – this paragraph needs to be clearer in providing the hierarchy of definitions and to say how to deal with any potential contradictions in definitions.

New text accepted at AdminWG audio/web 24-04-14.

Comment [RCG53]: AdminWG 010414 – agreed that date should be included as for other ISOs in the GTR. The title has also been included – which is the case for some ISO refs but not others.

NB: we may want to add the titles to ISOs that currently do not have them, e.g. ISO15031 in para 5.5.1. of main body.

Deleted: For the purpose of this document, the terms and definitions given in ISO 3833 and in paragraph 3 of II. Text of the Global Regulation apply.

3. Measurement criteria

3.1. Required overall measurement accuracy

The required overall measurement accuracy shall be as follows:

(a) Vehicle speed: ± 0.5 km/h or ± 1 per cent, whichever is greater;

(b) Time accuracy: min. ± 10 ms; time resolution: min. ± 0.01 s;

(c) Wheel torque (per torque meter): ± 3 Nm or ± 0.5 per cent of the maximum measured torque, whichever is greater;

(d) Wind speed: ± 0.3 m/s;

(e) Wind direction: ± 3°;

(f) Atmospheric temperature: ± 1 K;

(g) Atmospheric pressure: ± 0.3 kPa;

(h) Vehicle mass: ± 10 kg; (± 20 kg for vehicles > 4,000 kg)

(i) Tyre pressure: ± 5 kPa;

(j) Product of aerodynamic drag coefficient and frontal projected area ($C_d \times A_f$): ± 2 per cent;

(k) Chassis dynamometer roller speed: ± 0.5 km/h or ± 1 per cent, whichever is greater;

(l) Chassis dynamometer force: ± 10 N or ± 0.1 per cent of full scale, whichever is greater.

3.2. Wind tunnel criteria

The wind tunnel used for the determination of the product of aerodynamic drag coefficient C_d and frontal area A_f within the road load vehicle family shall meet the criteria in this paragraph.

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These criteria are only valid for determining $\Delta(C_d \times A_f)$ values in order to use the CO_2 interpolation method.

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3.2.1. Wind velocity

The wind velocity during a measurement shall remain within ± 2 km/h at the center of the test section. The possible wind velocity shall be at least 140 km/h.

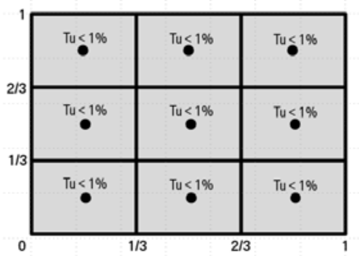
3.2.2. Air temperature

The air temperature during a measurement shall remain within ± 3 K at the center of the test section. The air temperature distribution at the nozzle outlet shall remain within ± 3K.

3.2.3. Turbulence

For an equally spaced 3 by 3 grid over the entire nozzle outlet the turbulence intensity, Tu, shall not exceed 1 per cent. See Figure A4/1.

Figure A4/1
Turbulence intensity



$$Tu = \frac{u'}{U_\infty} \qquad (1)$$

where:

Tu is turbulence intensity;

u' is turbulent velocity fluctuation, m/s;

U_∞ is free flow velocity, m/s.

3.2.4. Solid blockage

The vehicle blockage fraction, ε_{sb}, expressed as the quotient of the vehicle frontal area and the area of the nozzle outlet as shown in the following equation, shall not exceed 35 per cent.

$$\varepsilon_{sb} = \frac{A_f}{A_{nozzle}} \leq 35\ \% \qquad (2)$$

where:

ε_{sb} is vehicle blockage in per cent;

A_f is frontal area of vehicle, m²;

A_{nozzle} is the area of nozzle outlet, m².

3.2.5. Rotating wheels

To determine the aerodynamic influence of the wheels properly, the wheels of the test vehicle shall rotate at such a speed that the resulting vehicle velocity is within a ± 3 km/h tolerance of the wind velocity.

3.2.6. Moving belt

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Comment [RCG54]: Equation updated in GTR 230414 benchmark

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To simulate the fluid flow at the underbody of the test vehicle, the wind tunnel shall have a moving belt extending from the front to the rear of the vehicle. The speed of the moving belt shall be within ± 3 km/h of the wind velocity.

3.2.7. Fluid flow angle

At nine equally distributed points over the nozzle area, the root mean square deviation of both angles (Y-, Z-plane) α and β at the nozzle outlet shall not exceed 1°.

3.2.8. Air pressure

At nine equally distributed points over the nozzle area, the root mean square deviation of the total pressure at the nozzle outlet shall not exceed 2 per cent.

$$\sigma_{Pt} \times \left(\frac{\Delta P_t}{q}\right) < 2\ \%$$

where:

σ_{Pt} is the standard deviation of the total pressure;

ΔP_t is the variation of total pressure between the measurement points;

q is the dynamic pressure, N/ m².

The pressure coefficient, cp, over a distance 2 m ahead and 2 m behind the vehicle shall not deviate more than ±1 per cent.

$$\varepsilon_{cp} = \frac{cp_{x=2m}}{cp_{x=-2m}} \leq 1\ \% \qquad (3)$$

where:

cp is the pressure coefficient, N/m².

3.2.9. Boundary layer thickness

At $x = 0$ (balance center point), the wind velocity shall have at least 99 per cent of the inflow velocity 30 mm above the wind tunnel floor.

$\delta_{99}(x = 0\ m) \leq 30\ mm$

where:

δ_{99} is the distance perpendicular to the road, where 99 per cent of free stream velocity is reached (boundary layer thickness).

3.2.10. Restraint system

The restraint system mounting shall not be in front of the vehicle. The relative blockage fraction of the vehicle frontal area due to the restraint system, ε_{restr}, shall not exceed 10 per cent.

$$\varepsilon_{restr} = \frac{A_{restr}}{A_f} \leq 10\ \% \qquad (4)$$

where:

ε_{restr} is the relative blockage of the restraint system, per cent;

A_{restr} is the frontal area of the restraint system projected on the nozzle face, m²;

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Comment [RCG55]: Update from 230414 GTR benchmark

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Comment [RCG56]: Updates from 2301414 GTR benchmark

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A_f is the frontal area of the vehicle in m².

3.2.11. Measurement accuracy of the balance in x-direction

The inaccuracy of the resulting force in the x-direction shall not exceed ± 5 N. The resolution of the measured force shall be within ± 3 N.

3.2.12. Measurement repeatability

The repeatability of the measured force shall be within ± 3 N.

4. Road load measurement on road

4.1. Requirements for road test

4.1.1. Atmospheric conditions for road test

4.1.1.1. Permissible wind conditions

The maximum permissible wind conditions for road load determination are described in paragraphs 4.1.1.1.1. and 4.1.1.1.2.

In order to determine the applicability of the anemometry type to be used, the average wind speed shall be determined by continuous wind speed measurement, using a recognized meteorological instrument, at a location and height above the road level alongside the test road where the most representative wind conditions will be experienced.

If tests in opposite directions cannot be performed at the same part of the test track (e.g. on an oval test track with an obligatory driving direction), wind speed and direction at each part of the test track shall be measured. In this case the higher measured value determines the type of anemometry to be used and the lower value the criterion for the allowance of waiving of wind correction.

4.1.1.1.1. Permissible wind conditions when using stationary anemometry

Stationary anemometry shall be used only when wind speeds average less than 5 m/s and peak wind speeds are less than 8 m/s. In addition, the vector component of the wind speed across the test road shall be less than 2 m/s. The wind correction shall be conducted as given in paragraph 4.5.3.of this Sub-Annex. Wind correction may be waived when the lowest average wind speed is 3 m/s or less.

4.1.1.1.2. Wind conditions using on-board anemometry

For testing with an on-board anemometer, a device shall be used as described in paragraph 4.3.2. of this Sub-Annex. The overall average wind speed during the test activity over the test road shall be less than 7 m/s with peak wind speeds of less than 10 m/s. In addition, the vector component of the wind speed across the road shall be less than 4 m/s.

4.1.1.2. Atmospheric temperature

The atmospheric temperature should be within the range of 278 up to and including 313 K.

At its option, a manufacturer may choose to perform coastdowns between 274 and 278 K.

4.1.2. Test road

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Comment [RCG57]: AdminWG 010414 – text was included in GTR for India. Para can be deleted for EU.

Deleted: Contracting Parties may choose to permit more relaxed wind speed limits for coastdown test data using on-board anemometry from test facilities that are generally free from wind obstructions and thus providing stable wind conditions. In this case, the limits shall correspond to an overall average wind speed during the test activity over the test road that is less than 10 m/s with peak wind speeds of less than 14 m/s. In addition, the vector component of the wind speed across the road shall be less than 5 m/s.¶

Comment [RCG58]: AdminWG 010414 – Para not applicable for EU. Should be deleted.

Deleted: Contracting Parties may deviate from the upper range by ± 5 K on regional level.

The road surface shall be flat, clean, dry and free of obstacles or wind barriers that might impede the measurement of the road load, and its texture and composition shall be representative of current urban and highway road surfaces. The test road longitudinal slope shall not exceed ±1 per cent. The local slope between any points 3 m apart shall not deviate more than ±0.5 per cent from this longitudinal slope. If tests in opposite directions cannot be performed at the same part of the test track (e.g. on an oval test track with an obligatory driving direction), the sum of the longitudinal slopes of the parallel test track segments shall be between 0 and an upward slope of 0.1 per cent. The maximum camber of the test road shall be 1.5 per cent.

4.2. Preparation

4.2.1. Test vehicle

A test vehicle (vehicle H) shall be selected from the CO_2 vehicle family (see paragraph 5.6. of this Regulation) with the combination of road load relevant characteristics (i.e. mass, aerodynamic drag and tyre rolling resistance) producing the highest cycle energy demand.

At the request of the manufacturer, the CO_2 interpolation method may be applied for individual vehicles in the CO_2 vehicle family (see paragraph 1.2.3.1. of Sub-Annex 6 and paragraph 3.2.3.2. of Sub-Annex 7). In that case, the road load shall also be determined on a test vehicle (vehicle L) having a combination of road load relevant characteristics producing the lowest cycle energy demand.

Each test vehicle shall conform in all its components with the production series, or, if the vehicle is different from the production vehicle, a full description shall be included in the test report. If the manufacturer requests to use the CO_2 interpolation method, the increase or decrease in the product of the aerodynamic drag coefficient (C_d) and frontal area (A_f), m², expressed as Δf_2 for all of the optional equipment in the CO_2 vehicle family having an influence on the aerodynamic drag of the vehicle shall be included in the test report.

ACEA (W.Coleman) proposal: 16-05-14

Test vehicle

A test vehicle (vehicle H) shall be selected from the CO_2 vehicle family (see paragraph 5.6. of this gtr) with the combination of road load relevant characteristics (~~e.g.~~ **i.e.** mass, aerodynamic drag and tyre rolling resistance) producing the highest cycle energy demand.

At the request of the manufacturer, the CO_2 interpolation method may be applied for individual vehicles in the CO_2 vehicle family (see paragraph 1.2.3.1. of Annex 6 and paragraph 3.2.3.2. of Annex 7). In that case, the road load shall also be determined on a test vehicle (vehicle L) **and vehicles H and L shall have** ~~having~~ a combination of road load relevant characteristics producing **respectively** the **highest and** lowest cycle energy demand **required for the CO_2 interpolation**.

Each test vehicle shall ...

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Comment [RCG59]: An ACEA proposal for new text for this paragraph provided in the box that follows paragraph.

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Comment [RCG60]: A full description and aerodynamic options to be recorded in the Information Document.

Comment [RCG61]: AdminWG 290414 - it was agreed that "recorded" should remain as the term when it is used in relation to calculations and that it should be changed to "included in the test report" for when the information is documented in the test report.

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Alternative text in GTR 20.05.14

Each test vehicle shall conform in all its components with the production different from the production vehicle, a full description shall be recorde manufacturer requests to use the CO2 interpolation method, the increase or aerodynamic drag coefficient (C_d) and frontal area (A_f), m2, expressed as equipment in the CO2 vehicle family which;

a) has an influence on the aerodynamic drag of the vehicle, and

b) is to be included in the combined approach,

shall be recorded.

Comment [RCG62]: GTR OPEN POINT: 18.05.2014: approval from experts of this text and the deletion of the previous text is requested.

4.2.1.1. Movable aerodynamic body parts

Movable aerodynamic body parts on test vehicles shall operate during road load determination as intended under WLTP Type 1 test conditions (test temperature, speed and acceleration range, engine load, etc.).

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Appropriate requirements shall be added if future vehicles are equipped with movable aerodynamic options whose influence on aerodynamic drag justifies the need for further requirements.

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4.2.1.2 Wheels

If the manufacturer is not able to measure the aerodynamic drag of individual rotating wheels, the wheel with the highest expected aerodynamic drag shall be selected for test vehicles H and L.

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As a guideline, the highest aerodynamic drag may be expected for a wheel with a) the largest width, b) the largest diameter, and c) the most open structure design (in that order of importance).

4.2.1.3. Weighing

Before and after the road load determination procedure, the selected vehicle shall be weighed, including the test driver and equipment, to determine the average mass m_{av}. The mass of the vehicle shall be equal to or higher than the target test mass (TM_H) or TM_L, calculated according to paragraph 4.2.1.3.1. below at the start of the road load determination procedure.

For the test mass correction factor determination in paragraph 4.5.4. of this Sub-Annex, the actual test masses $TM_{H,actual}$ and $TM_{L,actual}$ will be used, i.e. the average mass m_{av} for the respective test masses.

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ACEA (W.Coleman) proposal

Weighing

Before and after the road load determination procedure, the selected vehicle shall be weighed, including the test driver and equipment, to determine the average mass m_{av}. The mass of the vehicle shall be equal to or higher than the target test mass ~~(TM_H) or TM_L~~ **of vehicle H or vehicle L**, ~~calculated according to paragraph 4.2.1.3.1. below~~ at the start of the road load determination procedure.

For the test mass correction factor determination in paragraph 4.5.4. of this Sub-Annex, the actual test masses $TM_{H,actual}$ and $TM_{L,actual}$ will be used, i.e. the average mass m_{av} for the respective test ~~masses~~**vehicles H and L**.

THEN DELETE PARAGRAPH 4.2.1.3.1.]

4.2.1.3.1. Vehicle test mass

The maximum and minimum values of test mass TM for vehicle H and vehicle L of the CO_2 vehicle family shall be calculated as follows:

TM_H shall be the sum of the mass in running order, the mass of the optional equipment of vehicle H, 25 kg, and the mass representative of the vehicle load.

TM_L shall be the sum of the mass in running order, 25 kg, and the mass representative of the vehicle load

The mass representative of the vehicle load shall be 15 per cent for category M vehicles or 28 per cent for category N vehicles from the vehicle load. The vehicle load is the difference between the technically permissible maximum laden mass (LM) and the sum of the mass in running order, 25 kg, and the mass of the optional equipment of vehicle H.

4.2.1.4. Test vehicle configuration

The test vehicle configuration shall be included in the test report and shall be used for any subsequent testing.

4.2.1.5. Test vehicle condition

4.2.1.5.1. Run-in

The test vehicle shall be suitably run-in for the purpose of the subsequent test for at least 10,000 but no more than 80,000 km.

4.2.1.5.1.1. At the request of the manufacturer, a vehicle with a minimum of 3,000 km may be used.

4.2.1.5.2. Manufacturer's specifications

The vehicle shall conform to the manufacturer’s intended production vehicle specifications regarding tyre pressures (paragraph 4.2.2.3. below), wheel alignment, ground clearance, vehicle height, drivetrain and wheel bearing lubricants, and brake adjustment to avoid unrepresentative parasitic drag.

4.2.1.5.3. Alignment

If an alignment parameter is adjustable (track, camber, caster), it shall be set to the nominal value of the manufacturer’s intended production vehicle. In absence of a nominal value, it shall be set to the mean of the values recommended by the manufacturer.

Such adjustable parameter(s) and set value shall be included in the test report.

4.2.1.5.4. Closed panels

During the road test, the engine bonnet, manually-operated moveable panels and all windows shall be closed.

4.2.1.5.5. Coastdown mode

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Comment [RCG63]: AdminWG 010414 – confirmed that “category 1” should be replaced by “category M” and “category 2” by “category N”

Comment [RCG64]: AdminWG 010414 – confirmed that text in brackets is not required.

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If the determination of dynamometer settings cannot meet the criteria described in paragraphs 8.1.3. or 8.2.3. of this Sub-Annex due to non-reproducible forces, the vehicle shall be equipped with a vehicle coastdown mode. The coastdown mode shall be approved and included in the test report.

4.2.1.5.5.1. If a vehicle is equipped with a vehicle coastdown mode, it shall be engaged both during road load determination and on the chassis dynamometer.

4.2.2. Tyres

4.2.2.1. Tyre selection

The selection of tyres shall be based on paragraph 4.2.1. with their rolling resistances measured according to Regulation No. 117-02, or an internationally accepted equivalent. The rolling resistance coefficients shall be aligned according to the respective regional procedures (e.g. EU 1235/2011), and categorised according to the rolling resistance classes in Table A4/1.

The actual rolling resistances values for the tyres fitted to the test vehicles shall be used as input for the calculation procedure of the CO_2 interpolation method in paragraph 3.2.3.2 of Annex 7. For individual vehicles in the CO_2 vehicle family, the CO_2 interpolation method shall be based on the RRC class value for the tyres fitted to the individual vehicle.

Alternative text proposed at AdminWG 290414

The selection of tyres shall be based on paragraph 4.2.1. with their rolling resistance classes determined according to EU 1235/2011.,.

For tyres fitted to the test vehicles and to individual vehicles in the CO_2 vehicle family, the CO_2 interpolation method shall be based on the RRC class values as shown in Table A4/1.

Table A4/1

Classes of rolling resistance coefficients (RRC) for tyre categories C1, C2 and C3, kg/tonne

Class	*C1 class value*	*C2 class value*	*C3 class value*
A	RRC = 5.9	RRC = 4.9	RRC = 3.5
B	RRC = 7.1	RRC = 6.1	RRC = 4.5
C	RRC = 8.4	RRC = 7.4	RRC = 5.5
E	RRC = 9.8	RRC = 8.6	RRC = 6.5
F	RRC = 11.3	RRC = 9.9	RRC = 7.5
G	RRC = 12.9	RRC = 11.2	RRC = 8.5

4.2.2.2. Tyre condition

Tyres used for the test shall:

(a) Not be older than 2 years after production date;

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Comment [RCG65]: AdminWG 290414 – delete "by the approval authority". To be confirmed.

AdminWG 080514 – to be agreed with Stephan Redmann & Helge Schmidt.

140514 – Helge Schmidt confirmed deletion

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Deleted: by the responsible authority
Comment [RCG66]: AdminWG 150514 – Paragraphs to be updated after discussions have been held with tyre experts and manufacturers.

Will need to keep reference to Reg No 107 as it provides details of the measurement procedure. NB: there is now a Revision 3 of Reg 117 – from Feb 2015

Reference to EU 1222/2009 required.

Comment [RCG67]: AdminWG 010414 – confirmed that "or an internationally accepted equivalent" should be deleted. Confirmed that "the respective regional procedures (e.g." should be deleted.

However is was considered that the text in this para and the para below Table A4/1 needs to be clarified. The issue had been raised in Vienna.

Iddo Riemersma to discuss with Norbert Ligterink.

AdminWG 290414 – paragraph rewritten. First half of table deleted as we only need the class value and not the range.

Comment [RCG68]: 23-May-2014

Delete table?

Values will change over time and we therefore need to provide x-refs to the other legislation and not to include the details in the WLTP (and also the GTR?).

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Comment [RCG69]: AdminWG 150514 – class numbers replaced with letters to match EU 1222/2009.
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(b) Not be specially conditioned or treated (e.g. heated or artificially aged), with the exception of grinding in the original shape of the tread;

(c) Be run-in on a road for at least 200 km before road load determination;

(d) Have a constant tread depth before the test between 100 and 80 per cent of the original tread depth over the full tread width of the tyre.

4.2.2.2.1. After measurement of tread depth, driving distance shall be limited to 500 km. If 500 km are exceeded, tread depth shall be measured again.

4.2.2.2.2. Tread depth shall be measured before performing another road load determination with the same tyres but on another vehicle.

4.2.2.3. Tyre pressure

The front and rear tyres shall be inflated to the lower limit of the tyre pressure range for the selected tyre at the coastdown test mass, as specified by the vehicle manufacturer.

4.2.2.3.1. Tyre-pressure adjustment

If the difference between ambient and soak temperature is more than 5 K, the tyre pressure shall be adjusted as follows:

(a) The tyres shall be soaked for more than 1 hour at 10 per cent above the target pressure;

(b) Prior to testing, the tyre pressure shall be reduced to the inflation pressure as specified in paragraph 4.2.2.3., adjusted for difference between the soaking environment temperature and the ambient test temperature at a rate of 0.8 kPa per 1 K using the following equation:

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$$\Delta p_t = 0.8 \times (T_{soak} - T_{amb}) \quad (5)$$

where:

Δp_t is the tyre pressure adjustment added to the tyre pressure defined in paragraph 4.2.2.3. of this Sub-Annex, kPa;

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0.8 is the pressure adjustment factor, kPa/K;

T_{soak} is the tyre soaking temperature, Kelvin (K);

T_{amb} is the test ambient temperature, Kelvin (K);

(c) Between the pressure adjustment and the vehicle warm-up, the tyres shall be shielded from external heat sources including sun radiation.

4.2.3. Instrumentation

Any instruments, especially those installed outside the vehicle, shall be installed in such a manner as to minimise effects on the aerodynamic characteristics of the vehicle.

4.2.4. Vehicle warm-up

4.2.4.1. On the road

Warming up shall be performed by driving the vehicle only.

4.2.4.1.1. Before warm-up, the vehicle shall be decelerated with the clutch disengaged or an automatic transmission in neutral by moderate braking from 80 to 20 km/h within 5 to 10 seconds. After this braking, there shall be no further manual adjustment of the braking system.

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4.2.4.1.2. Warming up and stabilization

All vehicles shall be driven at 90 per cent of the maximum speed of the applicable WLTC. The vehicle may be driven at 90 per cent of the maximum speed of the next higher phase (see Table A4/2) if this phase is added to the applicable WLTC warm-up procedure as defined in paragraph 7.3.4. of this Sub-Annex. The vehicle shall be warmed up for at least 20 min until stable conditions are reached.

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Table A4/2

Warming up and stabilization across phases

Vehicle class	*Applicable WLTC*	*90 per cent of maximum speed*	*Next higher phase*
Class1	Low_1+ $Medium_1$	58 km/h	NA
Class2	Low_2+ $Medium_2$+ $High_2$ + Extra $High_2$	111 km/h	NA
	Low_2+ $Medium_2$+ $High_2$	77 km/h	Extra High (111 km/h)
Class3	Low_3+ $Medium_3$+ $High_3$+ Extra $High_3$	118 km/h	NA
	Low_3+ $Medium_3$+ $High_3$	88 km/h	Extra High (118 km/h)

4.2.4.1.3. Criterion for stable condition

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Refer to paragraph 4.3.1.4.2. of this Sub-Annex.

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4.3. Measurement and calculation of total resistance by the coastdown method

The total resistance shall be determined by using the multi-segment (paragraph 4.3.1. of this Sub-Annex) or on-board anemometer (paragraph 4.3.2. of this Sub-Annex) method.

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4.3.1. Multi-segment method with stationary anemometry

4.3.1.1. Selection of reference speeds for road load curve determination

In order to obtain a road load curve as a function of vehicle speed, a minimum of six reference speeds v_j (j = 1, j = 2, etc.) shall be selected. The highest reference speed shall not be lower than the highest speed of the speed range, and the lowest speed point shall not be higher than the lowest speed of the speed range. The interval between each speed point shall not be greater than 20 km/h.

4.3.1.2. Data collection

During the test, elapsed time and vehicle speed shall be measured and recorded at a minimum rate of 5 Hz.

4.3.1.3. Vehicle coastdown procedure

4.3.1.3.1. Following the vehicle warm-up procedure (paragraph 4.2.4. of this Sub-Annex), and immediately prior to each test measurement, the vehicle may be driven at the highest reference speed up to a maximum of 1 minute. The vehicle shall be accelerated to at least 5 km/h above the speed at which the

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coastdown time measurement begins ($v_i + \Delta v$) and the coastdown shall be started immediately.

4.3.1.3.2. During coastdown, the transmission shall be in neutral, and the engine shall run at idle. Steering wheel movement shall be avoided as much as possible, and the vehicle brakes shall not be operated until the speed drops below ($v_j - \Delta v$).

4.3.1.3.3. The test shall be repeated until the coastdown data satisfy the statistical accuracy requirements as specified in paragraph 4.3.1.4.2.

4.3.1.3.4. Although it is recommended that each coastdown run be performed without interruption, split runs are permitted if data cannot be collected in a continuous way for the entire speed range. For split runs, care shall be taken so that vehicle conditions remain as stable as possible at each split point.

4.3.1.4. Determination of total resistance by coastdown time measurement

4.3.1.4.1. The coastdown time corresponding to reference speed v_j as the elapsed time from vehicle speed ($v_i + \Delta v$) to ($v_i - \Delta v$) shall be measured. It is recommended that $\Delta v = 5$ km/h with the option of $\Delta v = 10$ km/h when the vehicle speed is more than 60 km/h.

4.3.1.4.2. These measurements shall be carried out in both directions until a minimum of three consecutive pairs of measurements have been obtained which satisfy the statistical accuracy p, in per cent, defined below.

$$p = \frac{h \times \sigma}{\sqrt{n}} \times \frac{100}{\Delta t_j} \leq 3\ \% \qquad (6)$$

where:

p is the statistical accuracy;

n is the number of pairs of measurements;

Δt_j is the mean coastdown time at reference speed v_i, in seconds, given by the equation $\Delta t_j = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{ji}$, (7)

where Δt_{ji} is the harmonized average coastdown time of the i^th pair of measurements at velocity v_i, seconds (s), given by the equation: $\Delta t_{ji} = \frac{2}{\left(\frac{1}{\Delta t_{jai}}\right)+\left(\frac{1}{\Delta t_{jbi}}\right)}$. (8)

where Δt_{jai} and Δt_{jbi} are the coastdown times of the i^th measurement at reference speed v_i, in seconds (s),in each direction, respectively;

σ is the standard deviation, expressed in seconds (s), defined by: $\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta t_{ji} - \Delta t_j)^2}$ (9)

h is a coefficient given in Table A4/3.

Table A4/3
Coefficient h as function of n

n	*h*	*h/√n*	*n*	*h*	*h/√n*
3	4.3	2.48	10	2.2	0.73
4	3.2	1.60	11	2.2	0.66

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n	h	$h/\sqrt{n}$	n	h	$h/\sqrt{n}$
5	2.8	1.25	12	2.2	0.64
6	2.6	1.06	13	2.2	0.61
7	2.5	0.94	14	2.2	0.59
8	2.4	0.85	15	2.2	0.57
9	2.3	0.77			

4.3.1.4.3. 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.

4.3.1.4.4. The total resistances, F_{ja} and F_{jb} at reference speed v_i in directions a and b, in Newton (N), are determined by the equations:

$$F_{ja} = -\frac{1}{3.6} \times (m_{av} + m_r) \times \frac{2 \times \Delta v}{\Delta t_{ja}} \quad (10)$$

and

$$F_{jb} = -\frac{1}{3.6} \times (m_{av} + m_r) \times \frac{2 \times \Delta v}{\Delta t_{jb}} \quad (11)$$

where:

F_{ja} is the total resistance at reference speed (j) in direction a, in Newton (N);

F_{jb} is the total resistance at reference speed (j) in direction b, in Newton (N);

m_{av} is the average of the test vehicle masses at the beginning and end of road load determination, kg;

m_r is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdowns on the road, in kilograms (kg); m_r shall be measured or calculated using an appropriate technique agreed by the approval authority. Alternatively, m_r may be estimated to be 3 per cent of the sum of the mass in running order and 25 kg for the CO_2 vehicle family;

Δt_{ja} and Δt_{jb} are the mean coastdown times in directions a and b, respectively, corresponding to reference speed v_i, seconds (s), given by the equations $\Delta t_{ja} = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{jai}$ (12)

and $\Delta t_{jb} = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{jbi}$. (13)

4.3.1.4.5. The following equation shall be used to compute the average total resistance where the harmonized average of the alternate coastdown times shall be used.

$$F_j = -\frac{1}{3.6} \times (m_{av} + m_r) \times \frac{2 \times \Delta v}{\Delta t_j} \quad (14)$$

where:

Δt_j is the harmonized average of alternate coastdown time measurements at velocity v_i, seconds (s), given by $\Delta t_j = \frac{2}{\frac{1}{\Delta t_{ja}} + \frac{1}{\Delta t_{jb}}}$ (15)

Comment [RCG70]: GTR PROPOSAL: 19.05.2014: Experts requested to comment on whether the minus sign in front of equations 10, 11 and 14 should be removed.

Experts from Ford, BMW, UTAC agree that the minus sign should be removed.

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Comment [RCG71]: AdminWG 010414 – confirmed that "unladen" should be deleted. NB: there may be a change to this at end of June.

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Comment [RCG72]: AdminWG 010414 – It was pointed out that this sentence could be read in two ways which could lead to misinterpretation.

Amendment provided in 230414 GTR benchmark – in several places in GTR with same text/issue

Comment [RCG73]: Heinz Steven recommended that this para should be amended

I checked 4.3.1.4.5 of annex 4 and miss the equation with the coefficients f0 to f2. It is just mentioned how they should be calculated in the last sentence of this paragraph.
F0 to f2 are more explicitly mentioned in paragraph 4.5.5.1 of annex 4, but with the reference to 4.3.1.4.5 of annex 4 I recommend to amend 4.3.1.4.5!

where Δt_{ja} and Δt_{jb} are the coastdown times at velocity v_i, seconds (s),in each direction, respectively;

m_{av} is the average of the test vehicle masses at the beginning and end of road load determination, kg;

m_r is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdowns on the road, in kilograms (kg); m_r shall be measured or calculated using an appropriate technique. Alternatively, m_r may be estimated to be 3 per cent of the sum of the mass in running order and 25 kg for the CO_2 vehicle family.

The coefficients f_0, f_1 and f_2 in the total resistance equation shall be calculated with a least squares regression analysis.

4.3.2. On-board anemometer-based coastdown method

The vehicle shall be warmed up and stabilised according to paragraph 4.2.4. of this Sub-Annex. Calibration of instrumentation will take place during this time.

4.3.2.1. Additional instrumentation for on-board anemometry

The anemometer shall be calibrated by means of operation on the test vehicle where such calibration occurs during the warm-up for the test.

4.3.2.1.1. Relative wind speed shall be measured to an accuracy of 0.3 m/s and shall be recorded at a minimum of 1 Hz. Calibration of the anemometer shall include corrections for vehicle blockage.

4.3.2.1.2. Wind direction shall be relative to the direction of the vehicle. Relative wind direction (yaw) shall be measured to an accuracy of 3 degrees and recorded to a resolution of 1 degree; the "dead band" of the instrument shall not exceed 10 degrees and shall be directed toward the rear of the vehicle.

4.3.2.1.3. Before the coastdown, the anemometer shall be calibrated for speed and yaw offset as specified in ISO 10521-1:2006(E) Annex A.

4.3.2.1.4. Anemometer blockage shall be corrected for in the calibration procedure as described in ISO 10521-1:2006(E) Annex A.

4.3.2.2. Selection of speed range for road load curve determination

The test speed range as specified in paragraph 4.3.1.1. above shall be selected.

4.3.2.3. Data collection

Various data shall be measured and recorded during the procedure. Elapsed time, vehicle speed, and air velocity (speed, direction) relative to the vehicle, shall be measured at 5 Hz. Ambient temperature shall be synchronised and sampled at a minimum of 1 Hz.

4.3.2.4. Vehicle coastdown procedure

Vehicle coastdown shall be conducted as specified in paragraph 4.3.1.3. above with an on-board anemometer installed on the vehicle. A minimum of ten runs shall be made in alternating directions; five runs in each direction. Wind-corrected coastdown data must satisfy the statistical accuracy

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Comment [RCG74]: Amendment from 230414 GTR benchmark
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Comment [RCG75]: Simplified x-ref
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requirements as specified in paragraph 4.3.1.4.2. above. The anemometer shall be installed in a position such that the effect on the operating characteristics of the vehicle is minimised.

The anemometer shall be installed according to (a) or (b) below:

(a) Using a boom approximately 2 m in front of the vehicle's forward aerodynamic stagnation point.

(b) On the roof of the vehicle at its centreline. If possible, the anemometer shall be mounted within 15 cm. from the top of the windshield.

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In the event that position (b) is used, the coastdown results shall be analytically adjusted for the additional aerodynamic drag induced by the anemometer. The adjustment shall be made by testing the coastdown vehicle in a wind tunnel both with and without the anemometer installed (same position as used on the track), where the calculated difference will be the incremental drag coefficient (C_d), which combined with the frontal area can be used to correct the coastdown results.

4.3.2.5. Determination of the equation of motion

Symbols used in the on-board anemometer equations of motion are listed in Table A4/4.

Table A4/4

Symbols used in the on-board anemometer equations of motion

Symbol	*Units*	*Description*
A_f	m^2	frontal area
$a_0 \ldots a_n$	$degrees^{-1}$	coefficients for aerodynamic drag, as a function of yaw angle
Am	N	coefficient of mechanical drag
Bm	N/(km/h)	coefficient of mechanical drag
Cm	$N/(km/h)^2$	coefficient of mechanical drag
Baro	kPa	barometric pressure
Cd(Y)		coefficient of aerodynamic drag at yaw angle Y
D	N	drag
D_{aero}	N	aerodynamic drag
Df	N	front axle drag (including driveline)
D_{grav}	N	gravitational drag
D_{mech}	N	mechanical drag
D_r	N	rear axle drag (including driveline)
D_{tire}	N	tyre rolling resistance
(dv/dt)	m/s^2	acceleration
g	m/s^2	gravitational constant
m	kg	mass of vehicle
me	kg	effective vehicle mass (including rotating components)
ρ	kg/m3	air density
t	s	Time
T	K	Temperature
v	km/h	vehicle speed
vr	km/h	apparent wind speed relative to vehicle
Y	degrees	yaw angle of apparent wind relative to direction of vehicle travel

4.3.2.5.1. General form

The general form of the equation of motion can be written as shown below:

$$m_e\left(\frac{dv}{dt}\right) = D_{mech} + D_{aero} \quad (16)$$

where:

$$D_{mech} = D_{tyre} + D_f + D_r; \quad (17)$$

$$D_{aero} = \left(\frac{1}{2}\right)\rho C_d(Y)Av_r^2; \quad (18)$$

m_e is the effective vehicle mass.

4.3.2.5.2. Mechanical drag modelling

Although mechanical drag consists of separate components representing tire (D_{tire}), front and rear axle frictional losses (D_f and D_r, including transmissions losses), it can be modelled as a three-term polynomial with respect to speed (v), as in the equation below:

$$D_{mech} = A_m + B_m v + C_m v^2 \quad (19)$$

where:

A_m, B_m, and C_m are determined in the data analysis using the least squares method. These constants reflect the combined driveline and tyre drag.

4.3.2.5.3. Aerodynamic drag modelling

The aerodynamic drag coefficient $C_d(Y)$, is modelled as a four-term polynomial with respect to yaw angle (Y, deg), as in the equation below:

$$C_d(Y) = a_0 + a_1 Y + a_2 Y^2 + a_3 Y^3 + a_4 Y^4 \quad (20)$$

where a_0 to a_4 are constant coefficients whose values are determined in the data analysis. The aerodynamic drag coefficient is combined with the vehicle frontal area (A_f), and the relative wind velocity (v_r) to determine the aerodynamic drag (D_{aero}) according to the following two equations:

$$D_{aero} = \left(\frac{1}{2}\right)\rho A_f v_r^2 C_d(Y) \quad (21)$$

$$D_{aero} = \left(\frac{1}{2}\right)\rho A_f v_r^2 (a_0 + a_1 Y + a_2 Y^2 + a_3 Y^3 + a_4 Y^4) \quad (22)$$

4.3.2.5.4. Substituting, the final form of the equation of motion becomes:

$$m_e\left(\frac{dv}{dt}\right) =$$

$$A_m + B_m v + C_m v^2 + \left(\frac{1}{2}\right)\rho A v_r^2 (a_0 + a_1 Y + a_2 Y^2 + a_3 Y^3 + a_4 Y^4) \quad (23)$$

4.3.2.6. Data reduction

Techniques for analysing coastdown data shall be employed in the determination of the coefficients used to describe the road load force. A three-term equation shall be generated to describe the road load force as a function of velocity, $F = A + Bv + Cv^2$, corrected to standard ambient temperature and pressure conditions, and still air.

4.3.2.6.1. Determining calibration coefficients

If not previously determined, calibration factors to correct for vehicle blockage shall be determined for relative wind speed and yaw angle. Vehicle

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speed (v), relative wind velocity (v_r) and yaw (Y) measurements during the warm-up phase of the test procedure shall be recorded. Paired runs in alternate directions on the test track at a constant velocity of 80 km/h shall be performed, and averages for v, v_r and Y for each run shall be determined. Calibration factors that minimize the total errors in head and cross winds over all the run pairs, i.e. the sum of $(head_i - head_{i+1})^2$, etc., shall be selected where $head_i$ and $head_{i+1}$ refer to wind speed and wind direction from the paired test runs in opposing directions during the vehicle warm-up/stabilization prior to testing.

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4.3.2.6.2. Deriving second by second observations

From the periodic data collected during the coastdown runs, values for v, $\left(\frac{dv}{dt}\right)$, v_r^2, and Y shall be determined by applying calibration factors and data filtering to adjust samples to 1 Hz.

4.3.2.6.3. Preliminary analysis

Using a linear least squares regression technique, all data points shall be analysed at once. A_m, B_m, C_m, a_0, a_1, a_2, a_3 and a_4 given M_e, $\left(\frac{dv}{dt}\right)$, v, v_r, and ρ shall be determined.

4.3.2.6.4. Identifying "outliers"

For each data point, a predicted force, $m_e\left(\frac{dv}{dt}\right)$, shall be calculated and compared to that observed. Data points with excessive deviations, e.g., over three standard deviations, shall be flagged.

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4.3.2.6.5. Data filtering

If desired, appropriate data filtering techniques may be employed. Remaining data points shall be smoothed out.

4.3.2.6.6. Elimination of extreme data points

Data points with yaw angles greater than ± 20 degrees from the direction of vehicle travel shall be flagged. Data points with relative winds less than + 5 km/h (to avoid backwind conditions) shall also be flagged. Data analysis shall be restricted to vehicle speeds from 115 to 15 km/h.

4.3.2.6.7. Final data analysis

All data which has not been flagged shall be analysed using a linear least squares regression technique. Given M_e, $\left(\frac{dv}{dt}\right)$, v, v_r, and ρ, A_m, B_m, C_m, a_0, a_1, a_2, a_3, and a_4 shall be determined.

4.3.2.6.8. Constrained analysis option

In a constrained analysis, the vehicle frontal area A_f and the drag coefficient, C_d, are those values which have been previously determined.

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4.3.2.6.9. Correction to reference conditions

Equations of motion shall be corrected to reference conditions as specified in paragraph 4.5. of this Sub-Annex.

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4.4. Measurement of running resistance using the torque meter method

As an alternative to the coastdown methods, the torque meter method may also be used in which the running resistance is determined by measuring wheel torque on the driven wheels at various constant speeds with time periods of at least 5 seconds.

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4.4.1. Installation of torque meter

Wheel torque meters shall be installed between the wheel hub and the rim of each driven wheel, measuring the required torque to keep the vehicle at a constant speed.

4.4.2. Procedure and data sampling

4.4.2.1. Speed selection

The range of selected reference speeds v_j (j = 1, j = 2, etc.) where the running resistance is to be measured shall start at 15 km/h and cover the entire speed range of the applicable test cycle, while the difference between v_j and v_{j+1} is 20 km/h or less.

4.4.2.2. Start of data collection

Data collection shall be started after a vehicle warm-up according to paragraph 4.2.4. of this Sub-Annex.

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The reference speeds will be measured in a descending order. Upon the request of the manufacturer, stabilization periods are allowed between measurements but the stabilization speed shall not exceed the speed of the next reference speed.

4.4.2.3. Data collection

Data sets consisting of actual speed v_{ji}, actual torque C_{ji} and time over a period of at least 5 seconds shall be recorded for every v_j at a sampling frequency of at least 10 Hz. The data sets collected over one time period for a reference speed v_j will be referred to as one measurement.

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4.4.2.4. Velocity deviation

The velocity deviation v_{ji} from the mean velocity v_{jm} (paragraph 4.4.3. of this Sub-Annex) shall be within the values in Table A4/5.

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Table A4/5
Velocity deviation

Time period, seconds	*Velocity deviation, km/h*
5 - 10	± 0.2
10 - 15	± 0.4
15 - 20	± 0.6
20 - 25	± 0.8
25 - 30	± 1.0
≥ 30	± 1.2

4.4.3. Calculation of mean velocity and mean torque

4.4.3.1. Calculation process

Mean velocity v_{jm}, km/h, and mean torque C_{jm}, Nm, over a time period, shall be calculated from the data sets collected in paragraph 4.4.2.3. above as follows:

$$v_{jm} = \frac{1}{k}\sum_{i=1}^{k} v_{ji} \quad (24)$$

and

$$C_{jm} = \frac{1}{k}\sum_{i=1}^{k} C_{ji} - C_{js} \quad (25)$$

where:

v_{ji} is vehicle speed of the i[th] data set, km/h;

k is the number of data sets;

C_{ji} is torque of the i[th] data set, Nm;

C_{js} is the compensation term for speed drift, Nm, given by the following equation $C_{js} = (m_{av} + m_r) \times \alpha_j r_j$. (26)

C_{js} shall be no greater than 5 per cent of the mean torque before compensation, and may be neglected if α_j is not greater than ± 0.005 m/s².

m_{av} and m_r

are the average test vehicle mass and the equivalent effective mass, in kg, , respectively, defined in paragraph 4.3.1.4.4. above.

r' is the dynamic radius of the tyre, in meters (m), given by the equation

$$r' = \frac{1}{3.6} \times \frac{v_{jm}}{2\times\pi N}, \quad (27)$$

where N is the rotational frequency of the driven tyre, in s⁻¹;

α_j is the mean acceleration, in metres per second squared (m/s²), which shall be calculated by the equation

$$\alpha_j = \frac{1}{3.6} \times \frac{k\sum_{i=1}^{k} t_i v_{ji} - \sum_{i=1}^{k} t_i \sum_{i=1}^{k} v_{ji}}{k \times \sum_{i=1}^{k} t_i^2 - \left[\sum_{i=1}^{k} t_i\right]^2} \quad (28)$$

where t_i is the time at which the i[th] data set was sampled, seconds (s).

4.4.3.2. Accuracy of measurement

These measurements shall be carried out in opposite directions until a minimum of four consecutive figures at each v_i and in both directions (a and b) have been obtained, for which $\overline{C_j}$ satisfies the accuracy ρ, in per cent, according to the equation:

$$\rho = \frac{t \times s}{\sqrt{n}} \times \frac{100}{\overline{C_j}} \leq 3\ \% \quad (29)$$

where:

n is the number pairs of measurements for C_{jm};

$\overline{C_j}$ is the running resistance at the speed v_j, expressed in Nm, given by the equation:

$$\overline{C_j} = \frac{1}{n}\sum_{i=1}^{n} C_{jmi} \quad (30)$$

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where C_{jmi} is the average torque of the ith pair of measurements at speed v_j, expressed in Nm and given by:

$$C_{jmi} = \frac{1}{2} \times (C_{jmai} + C_{jmbi}) \qquad (31)$$

where C_{jmai} and C_{jmbi} are the mean torques of the ith measurement at speed v_j determined in paragraph 4.4.3.1. above for each direction, a and b respectively, expressed in Nm;

s is the standard deviation, expressed in Nm, defined by the equation

$$s = \sqrt{\frac{1}{k-1} \sum_{i=1}^{k} (C_{jmi} - \bar{C}_j)^2}; \qquad (32)$$

t is a coefficient from Table A4/3 in paragraph 4.3.1.4.2. above.

4.4.3.3. Validity of the measured average speed

The average speed, v_{jmi}, shall not deviate from its mean, $\bar{v}_j$, by more than ± 1 km/h or 2 per cent of the average speed v_{jmi}, whichever is greater. The values of $\bar{v}_j$ and v_{jmi} shall be calculated as follows:

$$\bar{v}_j = \frac{1}{n} \sum_{i=1}^{n} v_{jmi} \qquad (33)$$

$$v_{jmi} = \frac{1}{2} \times (v_{jmai} + v_{jmbi}) \qquad (34)$$

where v_{jmai} and v_{jmbi} are the mean speeds of the ith pair of measurements at velocity v_j determined in paragraph 4.4.3.1. above for each direction, a and b respectively, expressed in km/h.

4.4.4. Running resistance curve determination

The following least squares regression curves for each direction a and b shall be fitted to all the data pairs (v_{jm}, C_{jma}) and (v_{jm}, C_{jmb}) at all reference speeds v_j,(j = 1, j = 2, etc.) described in paragraph 4.3.1.1. above to determine the coefficients c_{0a}, c_{0b}, c_{1a}, c_{1b}, c_{2a} and c_{2b}:

$$C_a = c_{0a} + c_{1a}v + c_{2b}v^2 \qquad (35)$$

$$C_b = c_{0b} + c_{1b}v + c_{2b}v^2 \qquad (36)$$

where:

C_a and C_b are the running resistances in directions a and b, Nm;

c_{0a} and c_{0b} are constant terms in directions a and b, Nm;

c_{1a} and c_{1b} are the coefficients of the first-order term in directions a and b, Nm (h/km);

c_{2a} and c_{2b} are the coefficients of the second-order term in directions a and b, Nm (h/km)^2;

v is vehicle velocity, km/h.

The average total torque equation is calculated by the following equation:

$$C_{avg} = c_0 + c_1v + c_2v^2 \qquad (37)$$

where the average coefficients c_0, c_1 and c_2 shall be calculated using the following equations:

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Comment [RCG76]: GTR update 30.04.14
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Comment [RCG77]: GTR CORRECTION: 19.05.2014: Correction made by L. Hill
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$$c_0 = \frac{c_{0a}+c_{0b}}{2} \quad (38)$$

$$c_1 = \frac{c_{1a}+c_{1b}}{2} \quad (39)$$

$$c_2 = \frac{c_{2a}+c_{2b}}{2} \quad (40)$$

The coefficient c_1 may be assumed to be zero if the value of $(c_1 \times v)$ is no greater than 3 per cent of C at the reference speed(s); in this case, the coefficients c_0 and c_2 shall be recalculated according to the least squares method.

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The coefficients c_0, c_1 and c_2 as well as the coastdown times measured at the chassis dynamometer (see paragraph 8.2.3.3. of this Sub-Annex) shall be recorded.

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4.5. Correction to reference conditions

4.5.1. Air resistance correction factor

The correction factor for air resistance K_2 shall be determined as follows:

$$K_2 = \frac{T}{293} \times \frac{100}{P} \quad (41)$$

where:

T is the mean atmospheric temperature, Kelvin (K);

P is the mean atmospheric pressure, in kPa.

4.5.2. Rolling resistance correction factor

The correction factor, K_0, for rolling resistance, in Kelvin^{-1} (K^{-1}), may be determined based on empirical data and approved by the approval authority for the particular vehicle and tyre test, or may be assumed as follows:

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$K_0 = 8.6 \times 10^{-3}$

4.5.3. Wind correction with stationary anemometry

4.5.3.1. Wind correction, for absolute wind speed alongside the test road, shall be made by subtracting the difference that cannot be cancelled out by alternate runs from the constant term f_0 given in paragraph 4.3.1.4.5. above, or from c_0 given in paragraph 4.4.4. above. The wind correction shall not apply to the on-board anemometer-based coastdown method.

4.5.3.2. The wind correction resistance w_1 for the coastdown method or w_2 for the torque meter method shall be calculated by the equations:

$$w_1 = 3.6^2 \times f_2 \times v_w^2 \text{ or } w_2 = 3.6^2 \times c_2 \times v_w^2 \quad (42)$$

where:

w_1 is the wind correction resistance for the coastdown method, N;

f_2 is the coefficient of the aerodynamic term determined in paragraph 4.3.1.4.5. of this Sub-Annex;

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v_w is the lower average wind speed of both directions alongside the test road during the test, m/s;

w_2 is the wind correction resistance for the torque meter method, Nm;

c_2 is the coefficient of the aerodynamic term determined in paragraph 4.4.4. of this Sub-Annex.

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4.5.4. Test mass correction factor

4.5.4.1. Test vehicle H

The correction factor K_1 for the test mass of test vehicle H shall be determined as follows:

$$K_1 = f_0 \times \left(1 - \frac{TM_H}{TM_{H,actual}}\right) \qquad (43)$$

where:

f_0 is a constant term, N;

TM_H is test mass of the test vehicle H, kg;

$TM_{H,actual}$ is the actual test mass of test vehicle H (the average mass m_{av}); (see paragraph 4.3.1.4.4. of this Sub-Annex), kg.

4.5.4.2. Test vehicle L

The correction factor K_1 for the test mass of test vehicle L shall be determined as follows:

$$K_1 = f_0 \times \left(1 - \frac{TM_L}{TM_{L,actual}}\right) \qquad (44)$$

where:

f_0 is a constant term, N;

TM_L is test mass of test vehicle L, kg;

$TM_{L,actual}$ is the actual test mass of the test vehicle L (the average mass m_{av}, see paragraph 4.3.1.4.4. of this Sub-Annex), kg.

4.5.5. Road load curve correction

4.5.5.1. The curve determined in paragraph 4.3.1.4.5. of this Sub-Annex shall be corrected to reference conditions as follows and shall be used as the target coefficients in paragraph 8.1.1.:

$$F^* = \left((f_0 - w_1 - K_1) + f_1 v\right) \times \left(1 + K_0(T - 293\ K)\right) + K_2 f_2 v^2 \qquad (45)$$

where:

F^* is the corrected total resistance, N;

f_0 is the constant term, N;

f_1 is the coefficient of the first-order term, N (h/km);

f_2 is the coefficient of the second-order term, N $(h/km)^2$;

K_0 is the correction factor for rolling resistance as defined in paragraph 4.5.2. of this Sub-Annex;

K_1 is the test mass correction as defined in paragraph 4.5.4. of this Sub-Annex;

K_2 is the correction factor for air resistance as defined in paragraph 4.5.1. of this Sub-Annex;

v is vehicle velocity, km/h;

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Comment [RCG78]: ACEA (W.Coleman) proposal:

is **the target** test mass of the test vehicle H, kg:

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Comment [RCG79]: ACEA (W.Coleman) proposal:

is **the target** test mass of the test vehicle L, kg:

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Comment [RCG80]: Heinz Steven has made a comment that relates to this para.

I checked 4.3.1.4.5 of annex 4 and miss the equation with the coefficients f0 to f2. It is just mentioned how they should be calculated in the last sentence of this paragraph.
F0 to f2 are more explicitly mentioned in paragraph 4.5.5.1 of annex 4, but with the reference to 4.3.1.4.5 of annex 4
I recommend to amend 4.3.1.4.5!

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w_1 is the wind resistance correction as defined in paragraph 4.5.3. of this Sub-Annex.

4.5.5.2. The curve determined in paragraph 4.4.4. above shall be corrected to reference conditions as follows:

$$C^* = \left((c_0 - w_2 - K_1) + c_1 v\right) \times \left(1 + K_0(T - 293\ K)\right) + K_2 c_2 \rho v^2 \quad (46)$$

where:

C^* is the corrected total running resistance, Nm;

c_0 is the constant term, Nm;

c_1 is the coefficient of the first-order term, Nm (h/km);

c_2 is the coefficient of the second-order term, Nm $(h/km)^2$;

K_0 is the correction factor for rolling resistance as defined in paragraph 4.5.2. of this Sub-Annex;

K_1 is the test mass correction as defined in paragraph 4.5.4.;

K_2 is the correction factor for air resistance as defined in paragraph 4.5.1. of this Sub-Annex;

v is vehicle velocity, km/h;

w_2 is the wind correction resistance as defined in paragraph 4.5.3. of this Sub-Annex.

5. Method for the calculation of default road load based on vehicle parameters

5.1. As an alternative for determining road load with the coastdown or torque meter method, a calculation method for default road load may be used.

For the calculation of a default road load, several parameters such as test mass, width and height of the vehicle shall be used. The default road load (F_c) for several speeds v, in km/h, shall be calculated. Reference speeds shall be selected according to paragraph 4.3.1.1. and the default road load (F_c), in N, for these reference speeds v_j, in km/h, shall be calculated. The results of the calculated default road load values shall be used for the setting of the chassis dynamometer. A coastdown test on a chassis dynamometer shall be conducted to ensure the correct settings of the chassis dynamometer.

5.2. The default road load force shall be calculated using the following equation:

$$F_c = f_0 + f_1 \times v + f_2 \times v^2 \quad (47)$$

where:

F_c is the calculated default road load force for a given vehicle velocity v, and it is expressed in Newton (N);

f_0 is the constant road load coefficient, in N, defined by the equation: $f_0 = 0.140 \times TM$ (48)

f_1 is the first order road load coefficient and shall be equal to zero;

f_2 is the second order road load coefficient, in $N \cdot (h/km)^2$, defined by the equation:
$f_2 = (2.8 \times 10^{-6} \times TM) + (0.0170 \times width \times height)$ (49)

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v	is vehicle velocity, km/h;
TM	test mass, kg;
width	vehicle width, m, as defined in 6.2. of Standard ISO 612:1978;
height	vehicle height, m, as defined in 6.3. of Standard ISO 612:1978.

6. [RESERVED: Road load measurement using a combination of a wind tunnel and chassis dynamometer]

7. Transferring road load to a chassis dynamometer

7.1. Preparation for chassis dynamometer test

7.1.1. Laboratory condition

7.1.1.1. Roller

The chassis dynamometer roller(s) shall be clean, dry and free from foreign material which might cause tyre slippage. For chassis dynamometers with multiple rollers, the dynamometer shall be run in the same coupled or uncoupled state as the subsequent Type 1 test. Chassis dynamometer speed shall be measured from the roller coupled to the power-absorption unit.

7.1.1.1.1. Tyre slippage

Additional weight may be placed on or in the vehicle to eliminate tyre slippage. The manufacturer shall perform the load setting on the chassis dynamometer with the additional weight. The additional weight shall be present for both load setting and the emissions and fuel consumption tests. The use of any additional weight shall be included in the test report.

7.1.1.2. Room temperature

The laboratory atmospheric temperature shall be at a set point of 296 K and shall not deviate by more than ± 5 K during the test as the standard condition, unless otherwise required by the subsequent test(s).

7.2. Preparation of chassis dynamometer

7.2.1. Inertia mass setting

The equivalent inertia mass of the chassis dynamometer shall be set to the test mass used at the corresponding road load determination if a dual-axis chassis dynamometer is used. In case a single-axis chassis dynamometer is used, the equivalent inertia mass shall be increased by the inertia of the wheels and connected vehicle parts which are not rotating. If m_r is estimated at 3 per cent of the sum of the mass in running order and 25 kg, , the mass added to the inertia setting shall be 1.5 per cent of the sum of the mass in running order and 25 kg. If the chassis dynamometer is not capable to meet the inertia setting exactly, the next higher inertia setting shall be applied with a maximum increase of 10 kg.

ACEA (W.Coleman) proposal: - NB: based on WP29 version GTR text, not the updated text, as revised by S.Dubuc above

Inertia mass setting

The equivalent inertia mass of the chassis dynamometer shall be set to the

Comment [RCG82]: ACEA (W.Coleman) proposal: "vehicle width, **in** m, …

Comment [RCG83]: ACEA (W.Coleman) proposal: "vehicle height, **in** m, …

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Comment [RCG84]: 18.02.14 change in gtr to "slippage"

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Comment [RCG85]: Updates from 230414 GTR benchmark

Comment [RCG86]: GTR OPEN POINT: 18.05.2014: approval of the proposed changes requested.

test mass used at the corresponding road load determination if a dual-axis chassis dynamometer is used. In case a single-axis chassis dynamometer is used, the equivalent inertia mass shall be increased by ~~the inertia of the wheels and connected vehicle parts which are not rotating. If m_r is estimated at 3 per cent of the mass in running order plus 25 kg, the mass added to the inertia setting shall be~~ 1.5 per cent ~~of UM~~. If the chassis dynamometer is not capable to meet the inertia setting exactly, the next higher inertia setting shall be applied with a maximum increase of 10 kg.

7.2.2. Chassis dynamometer warm-up

The chassis dynamometer shall be warmed up in accordance with the dynamometer manufacturer's recommendations, or as appropriate, so that friction losses of the dynamometer can be stabilized.

7.3. Vehicle preparation

7.3.1. Tyre pressure adjustment

The tyre pressure at the soak temperature of a Type 1 test shall be set to no more than 50 per cent above the lower limit of the tyre pressure range for the selected tyre, as specified by the vehicle manufacturer (see paragraph 4.2.2.3. of this Sub-Annex), and shall be included in the test report.

7.3.2. If the determination of dynamometer settings cannot meet the criteria described in paragraph 8.1.3. of this Sub-Annex due to non-reproducible forces, the vehicle shall be equipped with a vehicle coastdown mode. The coastdown mode shall be approved and included in the test report.

7.3.2.1. If a vehicle is equipped with a vehicle coastdown mode, it shall be engaged both during road load determination and on the chassis dynamometer.

7.3.3. Vehicle setting

The tested vehicle shall be installed on the chassis dynamometer roller in a straight position and restrained in a safe manner. In case of a single roller, the tyre contact point shall be within ± 25 mm or ± 2 per cent of the roller diameter, whichever is smaller, measured from the top of the roller.

7.3.4. Vehicle warm-up

7.3.4.1. The vehicle shall be warmed up with the applicable WLTC. In case the vehicle was warmed up at 90 per cent of the maximum speed of the next higher phase during the procedure defined in paragraph 4.2.4.1.2. of this Sub-Annex, this higher phase shall be added to the applicable WLTC.

Table A4/6
Vehicle warm-up

Vehicle class	*Applicable WLTC*	*Adopt next higher phase*	*Warm-up cycle*
Class 1	Low_1+ $Medium_1$	NA	Low_1+ $Medium_1$
Class 2	Low_2+ $Medium_2$+ $High_2$+ Extra $High_2$	NA	
	Low_2+ $Medium_2$+ $High_2$	Yes (Extra $High_2$)	Low_2+ $Medium_2$ + $High_2$+ Extra $High_2$
		No	Low_2+ $Medium_2$+ $High_2$

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Comment [RCG87]: Editorial: This bracketed text 'gets in the way' here. Move to after "manufacturer"

S.Dubuc has amended GTR (23.04.14)

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Comment [RCG88]: AdminWG 290414 – error identified. S.Dubuc informed.

Comment [RCG89]: AdminWG 290414 – delete "by the approval authority". To be confirmed.

AdminWG 080514 – to be agreed with Stephan Redmann & Helge Schmidt.
140514 – Helge Schmidt confirmed deletion

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Vehicle class	*Applicable WLTC*	*Adopt next higher phase*	*Warm-up cycle*
Class 3	Low_3+ $Medium_3$+ $High_3$+ Extra $High_3$	Low_3+ $Medium_3$ + $High_3$+ Extra $High_3$	
	Low_3+ $Medium_3$+ $High_3$	Yes(Extra $High_3$)	Low_3+ $Medium_3$+ $High_3$+ Extra $High_3$
		No	Low_3+ $Medium_3$ + $High_3$

7.3.4.2. If the vehicle is already warmed up, the WLTC phase applied in paragraph 7.3.4.1. above, with the highest speed, shall be driven.

[RESERVED: alternative warm-up procedure]

8. Chassis dynamometer load setting

8.1. Chassis dynamometer setting by coastdown method

This method is applicable when the road load is determined using the coastdown method as specified in paragraph 4.3. of this Sub-Annex.

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8.1.1. Initial load setting

For a chassis dynamometer with coefficient control, the chassis dynamometer power-absorption unit shall be adjusted with the arbitrary initial coefficients, A_d, B_d and C_d, of the following equation:

$$F_d = A_d + B_d v + C_d v^2 \qquad (50)$$

where:

F_d is the chassis dynamometer setting load, N;

v is the speed of the chassis dynamometer roller, km/h.

The following are recommended coefficients to be used for the initial load setting:

(a) $A_d = 0.5 \times A_t, B_d = 0.2 \times B_t, C_d = C_t \qquad (51)$

for single-axis chassis dynamometers, or

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$A_d = 0.1 \times A_t, B_d = 0.2 \times B_t, C_d = C_t \qquad (52)$

for dual-axis chassis dynamometers, where A_t, B_t and C_t are the target road load coefficients;

(b) empirical values, such as those used for the setting for a similar type of vehicle.

For a chassis dynamometer of polygonal control, adequate load values at each reference speed shall be set to the chassis dynamometer power-absorption unit.

8.1.2. Coastdown

The coastdown test on the chassis dynamometer shall be performed with the procedure given in paragraphs 4.3.1.3.1. and 4.3.1.3.2. of this Sub-Annex.

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8.1.3. Verification

8.1.3.1. The target road load value shall be calculated using the target road load coefficient A_t, B_t and C_t for each reference speed v_j:

$$F_{tj} = A_t + B_t v_j + C_t v_j^2 \quad (53)$$

where:

F_{tj} is the target road load at reference speed v_j, N;

v_j is the j^{th} reference speed, km/h.

8.1.3.2. For dynamometer load setting, two different methods may be used. If the vehicle is accelerated by the dynamometer, the methods described in paragraph 8.1.3.2.1. below shall be used. If the vehicle is accelerated under its own power, the methods in paragraphs 8.1.3.2.1. or 8.1.3.2.2. below shall be used. The acceleration multiplied by speed shall be approximately 6 m²/sec³.

8.1.3.2.1. Fixed run method

For the fixed-run procedure, the dynamometer software shall automatically run three coastdowns adjusting the set coefficients for each run using the difference between the previous run's measured and target coefficients. The final set coefficients shall be calculated by subtracting the average of the vehicle coefficients obtained from the last two runs from the target coefficients. Optionally, a single stabilization coastdown may be performed before beginning the 2 run averaging sequence.

8.1.3.2.2. Iterative method

The calculated forces in the specified speed ranges shall be within a tolerance of ± 10 N after a least squares regression of the forces for two consecutive coastdowns.

If an error at any reference speed does not satisfy the criterion of the method described in this paragraph, paragraph 8.1.4. below shall be used to adjust the chassis dynamometer load setting.

8.1.4. Adjustment

The chassis dynamometer setting load shall be adjusted in accordance with the procedure specified in paragraph 1 of Appendix 2 to this Sub-Annex. Paragraphs 8.1.2. and 8.1.3. above shall be repeated.

8.2. Chassis dynamometer load setting using torque meter method

This method is applicable when the road load is determined using the torque meter method, as specified in paragraph 4.4. of this Sub-Annex.

8.2.1. Initial load setting

For a chassis dynamometer of coefficient control, the chassis dynamometer power absorption unit shall be adjusted with the arbitrary initial coefficients, A_d, B_d and C_d, of the following equation:

$$F_d = A_d + B_d v + C_d v^2 \quad (54)$$

where:

F_d is the chassis dynamometer setting load, N;

v is the speed of the chassis dynamometer roller, km/h.

The following coefficients are recommended for the initial load setting:

(a) $A_d = 0.5 \times \frac{a_t}{r'}, B_d = 0.2 \times \frac{b_t}{r'}, C_d = \frac{c_t}{r'}$ (55)

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(b) for single-axis chassis dynamometers, or

$$A_d = 0.1 \times \frac{a_t}{r'},\ B_d = 0.2 \times \frac{b_t}{r'},\ C_d = \frac{c_t}{r'} \qquad (56)$$

for dual-axis chassis dynamometers, where a_t, b_t and c_t are the coefficients for the target torque; r' is the dynamic radius of the tyre on the chassis dynamometer, m, obtained by averaging the r'_j values calculated in paragraph 2.1. of Appendix 1to this Sub-Annex;

(b) Empirical values, such as those used for the setting for a similar type of vehicle.

For a chassis dynamometer of polygonal control, adequate load values at each reference speed shall be set for the chassis dynamometer power-absorption unit.

8.2.2. Wheel torque measurement

The torque measurement test on the chassis dynamometer shall be performed with the procedure defined in paragraph 4.4.2. The torque meter(s) shall be identical to the one(s) used in the preceding road test.

8.2.3. Verification

8.2.3.1. The target road load value shall be calculated using the target torque coefficients a_t, b_t and c_t for each reference speed v_j.

$$F_{tj} = \frac{a_t + b_t \times v_j + c_t \times v_j^2}{r'} \qquad (57)$$

where:

F_{tj} is the target road load at reference speed v_j, N;

v_j is the j^{th} reference speed, km/h;

r' is the dynamic radius of the tyre on the chassis dynamometer, m, obtained by averaging the r'_j values calculated in paragraph 2.1 of Appendix 1 to this Sub-Annex.

8.2.3.2. The error, ε_j, in per cent of the simulated road load F_{sj} shall be calculated. F_{sj} is determined according to the method specified in paragraph 2. of Appendix 1 to this Sub-Annex, for target road load F_{tj} at each reference speed v_j.

$$\varepsilon_j = \frac{F_{sj} - F_{tj}}{F_{tj}} \times 100 \qquad (58)$$

$\frac{C_{jm}}{r'}$ obtained in paragraph 2.1.of Appendix 1 to this Sub-Annex, , may be used in the above equation instead of F_{sj}.

Errors at all reference speeds shall satisfy the following error criteria in two consecutive coastdown runs, unless otherwise specified by regulations.

$\varepsilon_j \leq 3$ per cent for $v_j \geq 50$ km/h

$\varepsilon_j \leq 5$ per cent for 20 km/h $< v_j < 50$ km/h

$\varepsilon_j \leq 10$ per cent for $v_j = 20$ km/h.

8.2.3.3. Adjustment

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Comment [RCG91]: 230414 GTR benchmark has replaced "*" with "x" in equation

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Comment [RCG92]: Updated in 230414 GTR benchmark

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Comment [RCG93]: What regulations are these? Amend text? Check with Rob Cuelenaere from TNO who is leading the Road Load Group for Phase 1b

E-mail query sent to Rob C. by TRL

The chassis dynamometer setting load shall be adjusted according to the procedure specified in paragraph 2 of Appendix 2 to this Sub-Annex. Paragraphs 8.2.2. and 8.2.3. shall be repeated.

Once the chassis dynamometer has been set within the specified tolerances, a vehicle coastdown shall be performed on the chassis dynamometer as outlined in paragraph 4.3.1.3. The coastdown times shall be recorded.

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Sub-Annex 4 - Appendix 1

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Calculation of road load for the dynamometer test

1. Calculation of simulated road load using the coastdown method

When the road load is measured by the coastdown method as specified in paragraph 4.3. of this Sub-Annex, calculation of the simulated road load F_{sj} for each reference speed v_j, in km per hour, shall be conducted as described in paragraphs 1.1. to 1.3. of this Appendix.

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1.1. The measured road load shall be calculated using the following equation:

$$F_{mj} = \frac{1}{3.6} \times (m_d + m'_r) \times \frac{2 \times \Delta v}{\Delta t_j} \quad (1)$$

where

F_{mj} is the measured road load for each reference speed v_j, N;

m_d is the equivalent inertia-mass of the chassis dynamometer, kg;

m'_r is the equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the road, kg; m'_r may be measured or calculated by an appropriate technique. As an alternative, m'_r may be estimated as 3 per cent of the sum of the mass in running order and 25 kg ;

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Δt_j is the coastdown time corresponding to speed v_j, s.

1.2. The coefficients A_s, B_s and C_s of the following approximate equation shall be determined using a least-square regression using the calculated values of F_{mj}:

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$$F_s = A_s + B_s v + C_s v^2 \quad (2)$$

1.3. The simulated road load for each reference speed v_j shall be determined using the following equation, using the calculated A_s, B_s and C_s:

$$F_{sj} = A_s + B_s v_j + C_s v_j^2 \quad (3)$$

2. Calculation of simulated road load using the torque meter method

When the road load is measured by the torque meter method as specified in paragraph 4.4. of Sub-Annex 4, calculation of the simulated road load F_{sj} for each reference speed v_j, in km per hour, shall be conducted as described in paragraphs 2.1. to 2.3. of this Appendix.

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2.1. The mean speed v_{jm}, in km per hour, and the mean torque C_{jm}, in Nm, for each reference speed v_j shall be calculated using the following equations:

$$v_{jm} = \frac{1}{k}\sum_{i=1}^{k} v_{ji} \quad (4)$$

and

$$C_{jm} = \frac{1}{k}\sum_{i=1}^{k} C_{ji} - C_{jc} \quad (5)$$

where:

v_{ji} is the vehicle speed of the ith data set, km/h;

k is the number of data sets;

C_{ji} is the torque of the ith data set, Nm;

C_{jc} is the compensation term for the speed drift, Nm, given by the following equation:

$$C_{jc} = (m_d + m'_r)\alpha_j r'_j \quad (6)$$

C_{jc} shall be no greater than 5 per cent of the mean torque before compensation, and may be neglected if $|\alpha_j|$ is no greater than 0.005 m/s^2.

m_d is the equivalent inertia mass of the chassis dynamometer, kg;

m'_r is the equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the dynamometer, kg; m'_r may be measured or calculated by an appropriatetechnique. As an alternative, m'_r may be estimated as 3 per cent of the sum of the mass in running order and 25 kg;

α_j is the mean acceleration, in metres per second squared (m/s^2), which shall be calculated by the equation:

$$\alpha_j = \frac{1}{3.6} \times \frac{k\sum_{i=1}^{k} t_i v_{ji} - \sum_{i=1}^{k} t_i \sum_{i=1}^{k} v_{ji}}{k\sum_{i=1}^{k} t_i^2 - \left(k\sum_{i=1}^{k} t_i\right)^2} \quad (7)$$

where t_i is the time at which the ith data set was sampled, seconds (s);

r'_j is the dynamic radius of the tyre, m, for the jth reference speed given by the equation:

$$r'_j = \frac{1}{3.6} \times \frac{v_{jm}}{2 \times \pi N} \quad (8)$$

where N is the rotational frequency of the driven tyre, s^{-1}.

2.2. The coefficients a_s, b_s and c_s of the following approximate equation shall be determined by the least-square regression using the calculated v_{jm} and the C_{jm}.

$$F_s = \frac{f_s}{r'} = \frac{a_s + b_s v + c_s v^2}{r'} \quad (9)$$

2.3. The simulated road load for each reference speed v_j shall be determined using the following equation and the calculated a_s, b_s and c_s:

$$F_{sj} = \frac{f_{sj}}{r'} = \frac{a_s + b_s v_j + c_s v_j^2}{r'} \quad (10)$$

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Comment [RCG95]: Updated in 230414 GTR benchmark

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Sub-Annex 4 - Appendix 2

Adjustment of chassis dynamometer load setting

1. Adjustment of chassis dynamometer load setting using the coastdown method

The chassis dynamometer load setting shall be adjusted using the following equations:

$$F_{dj}^{*} = F_{dj} - F_j = F_{dj} - F_{sj} + F_{tj} =$$

$$= \left(A_d + B_d v_j + C_d v_j^2\right) - \left(A_s + B_s v_j + C_s v_j^2\right) + \left(A_t + B_t v_j + C_t v_j^2\right) =$$

$$= (A_d + A_t - A_s) + (B_d + B_t - B_s) v_j + (C_d + C_t - C_s) v_j^2 \qquad (1)$$

Therefore:

$$A_d^{*} = A_d + A_t - A_s \qquad (2)$$

$$B_d^{*} = B_d + B_t - B_s \qquad (3)$$

$$C_d^{*} = C_d + C_t - C_s \qquad (4)$$

The parameters used in these equations are the following:

F_{dji}	is the initial chassis dynamometer setting load, N;
F_{dj}^{*}	is the adjusted chassis dynamometer setting load, N;
F_j	is the adjustment road load, which is equal to $F_{sj} - F_{tj}$ N;
F_{sj}	is the simulated road load at reference speed v_j, N;
F_{tj}	is the target road load at reference speed v_j, N;
A_d^{*}, B_d^{*} and C_d^{*}	are the new chassis dynamometer setting coefficients.

Comment [RCG96]: GTR CORRECTION: 19.05.2014: Supplied by L. Hill.

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Comment [RCG97]: GTR CORRECTION: 19.05.2014: Supplied by L. Hill.

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2. Adjustment of chassis dynamometer load setting using the torque meter method

The chassis dynamometer load setting shall be adjusted using the following equation:

$$F_{dj}^{*} = F_{dj} - \frac{F_{ej}}{r'} = F_{dj} - \frac{F_{sj}}{r'} + \frac{F_{tj}}{r'} =$$

$$= \left(A_d + B_d v_j + C_d v_j^2\right) - \frac{\left(a_s + b_s v_j + c_s v_j^2\right)}{r'} + \frac{\left(a_t + b_t v_j + c_t v_j^2\right)}{r'} =$$

$$= \left\{A_d + \frac{(a_t - a_s)}{r'}\right\} + \left\{B_d + \frac{(b_t - b_t)}{r'}\right\} v_j + \left\{C_d + \frac{(c_t - c_s)}{r'}\right\} v_j^2 \qquad (5)$$

Therefore:

$$A_d^{*} = A_d + \frac{a_t - a_s}{r'} \qquad (6)$$

$$B_d^{*} = B_d + \frac{b_t - b_s}{r'} \qquad (7)$$

$$C_d^{*} = C_d + \frac{c_t - c_s}{r'} \qquad (8)$$

where:

F^*_{dj} is the new chassis dynamometer setting load, N;

F_{ej} is the adjustment road load, which is equal to $(F_{sj} - F_{tj})$, Nm;

F_{sj} is the simulated road load at reference speed v_j, Nm;

F_{tj} is the target road load at reference speed v_j, Nm;

A^*_d, B^*_d and C^*_d are the new chassis dynamometer setting coefficients;

r' is the dynamic radius of the tyre on the chassis dynamometer, m, that is obtained by averaging the r'_j values calculated in paragraph 2.1. of Appendix 1 to Sub-Annex 4.

Comment [RCG98]: GTR update 13.05.14

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Submitted by the European Commission

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69th GRPE, 5 – 6 June 2014
Agenda item 3a

Sub-Annex 5

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Test equipment and calibrations

1. Test bench specifications and settings

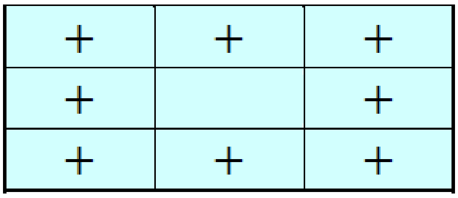
1.1. Cooling fan specifications

1.1.1. A current of air of variable speed shall be blown towards the vehicle. The set point of the linear velocity of the air at the blower outlet shall be equal to the corresponding roller speed above roller speeds of 5 km/h. The deviation of the linear velocity of the air at the blower outlet shall remain within ± 5 km/h or ± 10 per cent of the corresponding roller speed, whichever is greater.

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

(a) For fans with rectangular outlets, are located at the centre of each rectangle dividing the whole of the fan outlet into 9 areas (dividing both horizontal and vertical sides of the fan outlet into 3 equal parts). The centre area shall not be measured (as shown in Figure A5/1);

Figure A5/1
Fan with rectangular outlet



(b) For circular fan outlets, the outlet shall be divided into 8 equal sections by vertical, horizontal and 45° lines. The measurement points lie on the radial centre line of each arc (22.5°) at two-thirds of the outlet radius (as shown in Figure A5/2).

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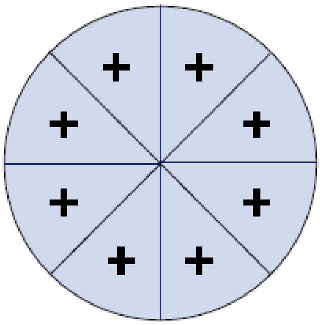
Figure A5/2
Fan with circular outlet



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 between 0 and 20 cm from the air outlet.

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1.1.3. The outlet of the fan shall have the following characteristics:

(a) An area of at least 0.3 m^2, and,

(b) A width/diameter of at least 0.8 m.

1.1.4. The position of the fan shall be as follows:

(a) Height of the lower edge above ground: approximately 20 cm;

(b) Distance from the front of the vehicle: approximately 30 cm.

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

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1.1.6. In the cases described above, the cooling fan position (height and distance) shall be included in the test report and shall be used for any subsequent testing.

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2. Chassis dynamometer

2.1. General requirements

2.1.1. The dynamometer shall be capable of simulating road load with at least three road load parameters that can be adjusted to shape the load curve.

2.1.2. The chassis dynamometer may have one or two rollers. In the case of twin-roll dynamometers, the rollers shall be permanently coupled or the front roller shall drive, directly or indirectly, any inertial masses and the power absorption device.

2.2. Specific requirements

The following specific requirements relate to the dynamometer manufacturer's specifications.

2.2.1. The roll run-out shall be less than 0.25 mm at all measured locations.

2.2.2. The roller diameter shall be within ± 1.0 mm of the specified nominal value at all measurement locations.

2.2.3. The dynamometer shall have a time measurement system for use in determining acceleration rates and for measuring vehicle/dynamometer coastdown times. This time measurement system shall have an accuracy of ± 0.001 per cent or better. This shall be verified upon initial installation.

2.2.4. The dynamometer shall have a speed measurement system with an accuracy of ± 0.080 km/h or better. This shall be verified upon initial installation.

2.2.5. The dynamometer shall have a response time (90 per cent response to a tractive effort step change) of less than 100 ms with instantaneous accelerations which are at least 3 m/s^2. This shall be verified upon initial installation and after major maintenance.

2.2.6. The base inertia weight of the dynamometer shall be stated by the dynamometer manufacturer, and must be confirmed to within ± 0.5 per cent for each measured base inertia and ± 0.2 per cent relative to any mean value by dynamic derivation from trials at constant acceleration, deceleration and force.

2.2.7. Roller speed shall be recorded at a frequency of not less than 1 Hz.

2.3. Additional specific requirements for chassis dynamometers for vehicles to be tested in four wheel drive (4WD) mode

2.3.1. The 4WD control system shall be designed such that the following requirements are met when tested with a vehicle driven over the WLTC.

2.3.1.1. Road load simulation shall be applied such that operation in 4WD mode reproduces the same proportioning of forces as would be encountered when driving the vehicle on a smooth, dry, level road surface.

2.3.1.2. The difference in distance covered by the front and rear rolls shall be less than 0.1 m in any 200 ms time period. If it can be demonstrated that this criterion is met, the speed synchronization requirement in paragraph 2.3.1.3. below is not required. This must be checked for new dynamometer instalments and after major repairs or maintenance.

2.3.1.3. All roll speeds shall be synchronous to within ± 0.16 km/h. This may be assessed by applying a 1s moving average filter to roll speed data acquired at a minimum of 20 Hz. This must be checked for new dynamometer instalments and after major repairs or maintenance.

2.3.1.4. The difference in distance covered by the front and rear rolls shall be less than 0.2 per cent of the driven distance over the WLTC. The absolute number shall be integrated for the calculation of the total difference in distance over the WLTC.

2.4. Chassis dynamometer calibration

2.4.1. Force measurement system

The accuracy and linearity of the force transducer shall be at least ± 10 N for all measured increments. This shall be verified upon initial installation, after major maintenance and within 370 days before testing.

2.4.2. Dynamometer parasitic loss calibration

The dynamometer's parasitic losses shall be measured and updated if any measured value differs from the current loss curve by more than 2.5 N. This shall be verified upon initial installation, after major maintenance and within 35 days before testing.

2.4.3. Verification of road load simulation without a vehicle

The dynamometer performance shall be verified by performing an unloaded coastdown test upon initial installation, after major maintenance, and within 7 days before testing. The average coastdown force error shall be less than 10 N or 2 per cent, whichever is greater, at each measured point (10 km/h speed intervals) in the speed range.

3. Exhaust gas dilution system

3.1. System specification

3.1.1. Overview

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3.1.1.1. A full flow exhaust dilution system shall be used. The total vehicle exhaust shall be continuously diluted with ambient air under controlled conditions using a constant volume sampler. A critical flow venturi (CFV) or multiple critical flow venturis arranged in parallel, a positive displacement pump (PDP), a subsonic venturi (SSV), or an ultrasonic flow meter (USM) may be used. 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 exhaust gas compounds are determined from the sample concentrations, corrected for their respective content of the dilution air and the totalised flow over the test period.

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3.1.1.2. The exhaust dilution system shall consist of a connecting tube, a mixing device and dilution tunnel, dilution air conditioning, a suction device and a flow measurement device. Sampling probes shall be fitted in the dilution tunnel as specified in paragraphs 4.1., 4.2. and 4.3. of this Sub-Annex.

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3.1.1.3. The mixing device referred to in paragraph 3.1.1.2. shall be a vessel such as that illustrated in Figure A5/3 in which vehicle exhaust gases and the dilution air are combined so as to produce a homogeneous mixture at the sampling position.

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3.2. General requirements

3.2.1. 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.

3.2.2. The mixture of air and exhaust gases shall be homogeneous at the point where the sampling probes are located (paragraph 3.3.3. below). The sampling probes shall extract representative samples of the diluted exhaust gas.

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

3.2.4. The sampling system shall be gas-tight. The design of the variable-dilution sampling system and the materials used in its construction shall be such that they do not affect the compound concentration in the diluted exhaust gases. If any component in the system (heat exchanger, cyclone separator, suction device, etc.) changes the concentration of any of the exhaust gas compounds in the diluted exhaust gases and the systematic error cannot be corrected, sampling for that compound shall be carried out upstream from that component.

3.2.5. All parts of the dilution system in contact with raw or diluted exhaust gas shall be designed to minimise 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.

3.2.6. 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 their operation.

3.3. Specific requirements

3.3.1. Connection to vehicle exhaust

3.3.1.1. The start of the connecting tube is the exit of the tailpipe. The end of the connecting tube is the sample point, or first point of dilution. For multiple tailpipe configurations where all the tailpipes are combined, the start of the connecting tube may be taken at the last joint of where all the tailpipes are combined.

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

3.3.1.3. The connecting tube shall 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 shall not exceed 105 mm; the insulating materials shall have a thickness of at least 25 mm and thermal conductivity not exceeding 0.1 $W/m^{-1}K^{-1}$ at 400°C. Optionally, the tube may be heated to a temperature above the dew point. This may be assumed to be achieved if the tube is heated to 70 °C;

(b) 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 duration of the test from the static pressures recorded when nothing is connected to the vehicle exhaust pipes. 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 tailpipe. 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 approval authority substantiates the need for the closer tolerance;

(c) No component of the connecting tube shall be of a material which might affect the gaseous or solid composition of the exhaust gas. To avoid generation of any particles from elastomer connectors, elastomers employed shall be as thermally stable as possible and have minimum exposure to the exhaust gas. It is recommended not to use elastomer connectors to bridge the connection between the vehicle exhaust and the connecting tube.

3.3.2. Dilution air conditioning

3.3.2.1. The dilution air used for the primary dilution of the exhaust in the CVS tunnel shall be passed through a medium capable of reducing particles of the most penetrating particle size in the filter material by ≤ 99.95 per cent, or through a filter of at least class H13 of EN 1822:2009. 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 be situated before the HEPA filter and after the charcoal scrubber, if used.

3.3.2.2. 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 and particle number levels, which can then be subtracted from the values measured in the diluted exhaust. See paragraph 1.2.1.3. of Sub-Annex 6.

3.3.3. Dilution tunnel

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

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

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

(a) Consists of a straight tube of electrically-conductive material, which shall be grounded;

(b) Shall cause turbulent flow (Reynolds number ≥ 4,000) and be 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 and/or heated.

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3.3.4. Suction device

3.3.4.1. This device may have a range of fixed speeds to ensure sufficient flow to prevent any water condensation. This result is 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 per cent by volume for petrol and diesel, less than 2.2 per cent by volume for LPG and less than 1.5 per cent by volume for NG/biomethane.

3.3.4.2. Compliance with the above requirements may not be necessary if the CVS system is designed to inhibit condensation by such techniques, or combination of techniques, as:

(a) Reducing water content in the dilution air (dilution air dehumidification);

(b) Heating of the CVS dilution air and of all components up to the diluted exhaust flow measurement device, and optionally, the bag sampling system including the sample bags and also the system for the measurement of the bag concentrations.

In such cases, the selection of the CVS flow rate for the test shall be justified by showing that condensation of water cannot occur at any point within the CVS, bag sampling or analytical system.

3.3.5. Volume measurement in the primary dilution system

3.3.5.1. The method of measuring total dilute exhaust volume incorporated in the constant volume sampler shall be such that measurement is accurate to ± 2 per cent 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 for a PDP-CVS, ± 11 K for a CFV CVS, ± 6 K for a USM CVS, and ± 11 K for an SSV CVS.

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

3.3.5.3. 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 second at 62 per cent of a given temperature variation (value measured in silicone oil).

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

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

3.3.6. Recommended system description

Figure A5/3 is a schematic drawing of exhaust dilution systems which meet the requirements of this Sub-Annex.

The following components are recommended:

(a) A dilution air filter, which can be pre-heated if necessary. This filter shall consist of the following filters in sequence: an optional activated charcoal filter (inlet side), and a 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;

(b) A connecting tube by which vehicle exhaust is admitted into a dilution tunnel;

(c) An optional heat exchanger as described in paragraph 3.3.5.1. above;

(d) A mixing device in which exhaust gas and dilution air are mixed homogeneously, and which may be located close to the vehicle so that the length of the connecting tube is minimized;

(e) A dilution tunnel from which particulates and particles are sampled;

(f) Some form of protection for the measurement system may be used e.g. a cyclone separator, bulk stream filter, etc.;

(g) A suction device of sufficient capacity to handle the total volume of diluted exhaust gas.

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.

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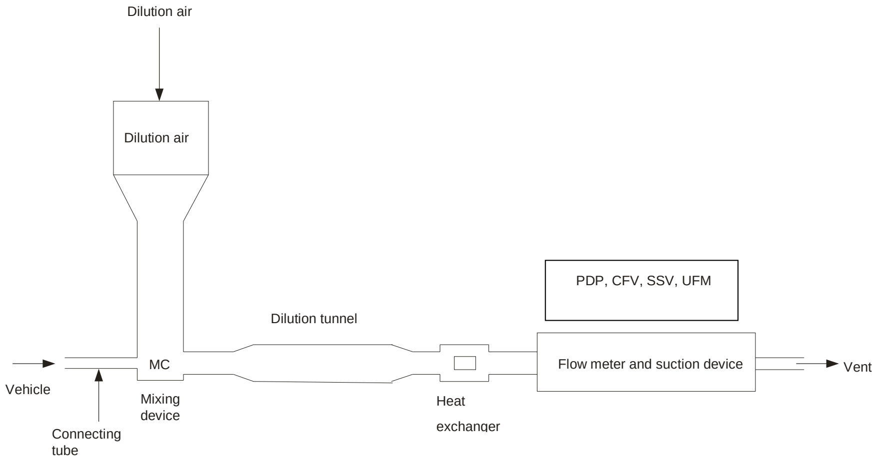
Figure A5/3
Exhaust Dilution System



3.3.6.1. Positive displacement pump (PDP)

3.3.6.1.1. A positive displacement pump (PDP) full flow exhaust dilution system satisfies the requirements of this Sub-Annex 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.

3.3.6.2. Critical flow venturi (CFV)

3.3.6.2.1. The use of a critical flow venturi (CFV) for the full flow exhaust 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.

3.3.6.2.2. 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 Sub-Annex are met.

3.3.6.2.3. A measuring critical flow venturi (CFV) tube shall measure the flow volume of the diluted exhaust gas.

3.3.6.3. Subsonic flow venturi (SSV)

3.3.6.3.1. The use of a subsonic venturi (SSV) (Figure A5/4) for a full flow exhaust dilution system is based on the principles of flow mechanics. The variable

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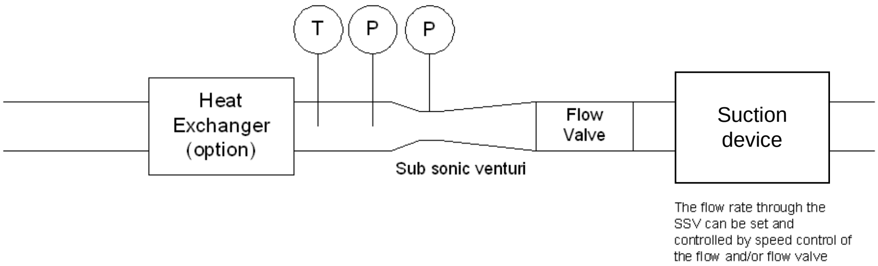
mixture flow rate of dilution and exhaust gas is maintained at a subsonic velocity which is calculated from the physical dimensions of the subsonic venturi and measurement of the absolute temperature and pressure at the venturi inlet and the pressure in the throat of the venturi. Flow is continually monitored, computed and integrated throughout the test.

3.3.6.3.2. An SSV shall measure the flow volume of the diluted exhaust gas.

Figure A5/4
Schematic of a supersonic venture tube (SSV)



3.3.6.4. Ultrasonic flow meter (USM)

3.3.6.4.1. A USM measures the velocity of the diluted exhaust gas using ultra-sonic transmitters/detectors as in Figure A5/5. The gas velocity is converted to standard volumetric flow using a calibration factor for the tube diameter with real time corrections for the diluted exhaust temperature and absolute pressure.

3.3.6.4.2. Components of the system include:

(a) A suction device fitted with speed control, flow valve or other method for setting the CVS flow rate and also for maintaining constant volumetric flow at standard conditions;

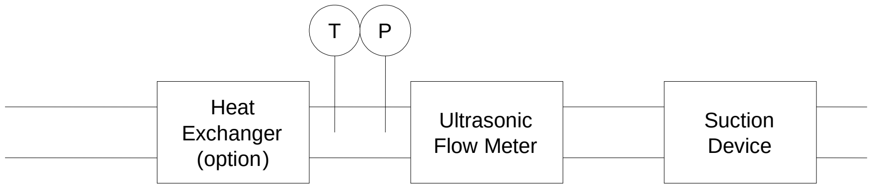
(b) A USM;

(c) Temperature (T) and pressure (P) measurement devices required for flow correction;

(d) An optional heat exchanger for controlling the temperature of the diluted exhaust to the USM. If installed, the heat exchanger should be capable of controlling the temperature of the diluted exhaust to that specified in paragraph 3.3.5.1. above. Throughout the test, the temperature of the air/exhaust gas mixture measured at a point immediately upstream of the suction device shall be within ± 6 K of the average operating temperature during the test.

Figure A5/5

Schematic of an ultrasonic flow meter (USM)



3.3.6.4.3. The following conditions shall apply to the design and use of the USM type CVS:

(a) The velocity of the diluted exhaust gas shall provide a Reynolds number higher than 4,000 in order to maintain a consistent turbulent flow before the ultrasonic flow meter;

(b) An ultrasonic flow meter shall be installed in a pipe of constant diameter with a length of 10 times the internal diameter upstream and 5 times the diameter downstream;

(c) A temperature sensor for the diluted exhaust shall be installed immediately before the ultrasonic flow meter. This sensor shall have an accuracy and a precision of ± 1 K and a response time of 0.1 second at 62 per cent of a given temperature variation (value measured in silicone oil);

(d) The absolute pressure of the diluted exhaust shall be measured immediately before the ultrasonic flow meter to an accuracy of less than ± 0.3 kPa;

(e) If a heat exchanger is not installed upstream of the ultrasonic flow meter, the flow rate of the diluted exhaust, corrected to standard conditions shall be maintained at a constant level during the test. This may be achieved by control of the suction device, flow valve or other method.

3.4. CVS calibration procedure

3.4.1. General requirements

3.4.1.1. The CVS system shall be calibrated by using an accurate flow meter and a restricting device and at the intervals listed in Table A5/4. 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 (e.g. calibrated venturi, laminar flow element, calibrated turbine meter) 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.

3.4.1.2. The following paragraphs describe methods for calibrating PDP, CFV, SSV and UFM units using a laminar flow meter, which gives the required accuracy, along with a statistical check on the calibration validity.

3.4.2. Calibration of a positive displacement pump (PDP)

3.4.2.1. The following calibration procedure outlines the equipment, the test configuration and the various parameters that are measured to establish the

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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 m^3/min at pump inlet for the measured absolute pressure and temperature) can subsequently be plotted versus a correlation function which includes the relevant pump parameters. The linear equation that relates the pump flow and the correlation function shall then be determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.

3.4.2.2. 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. The following conditions shall be maintained to ensure the accuracy and integrity of the calibration curve:

3.4.2.2.1. 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.

3.4.2.2.2. 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.

3.4.2.2.3. All connections between the flow meter and the CVS pump shall be free of leakage.

3.4.2.3. During an exhaust emission test, the measured pump parameters shall be used to calculate the flow rate from the calibration equation.

3.4.2.4. Figure A5/6 of this Sub-Annex shows an example of a calibration set-up. Variations are permissible, provided that the approval authority approves them as being of comparable accuracy. If the set-up shown in Figure A5/6 is used, the following data shall be found within the limits of accuracy given:

Barometric pressure (corrected) (P_b)	± 0.03 kPa
Ambient temperature (T)	± 0.2 K
Air temperature at LFE (ETI)	± 0.15 K
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

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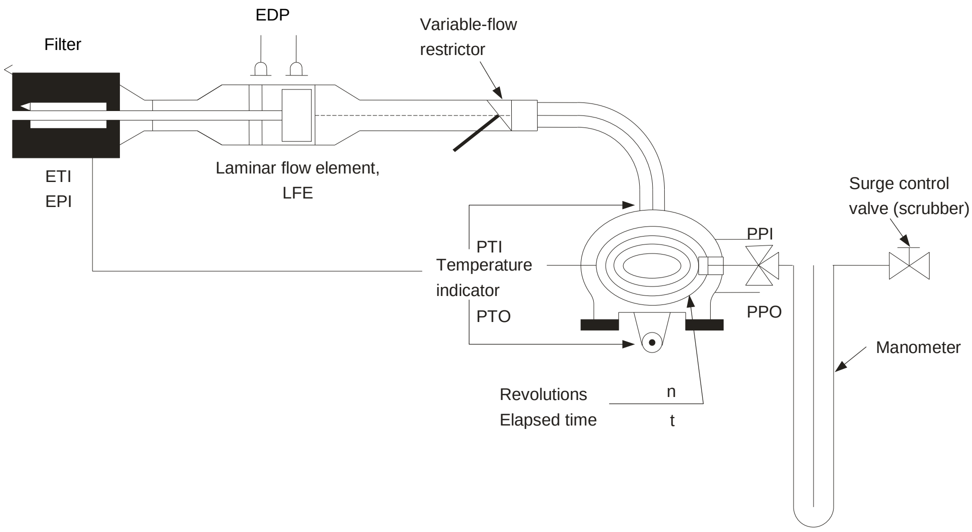
Figure A5/6

PDP Calibration Configuration



3.4.2.5. After the system has been connected as shown in Figure A5/6, the variable restrictor shall be set in the wide-open position and the CVS pump shall run for 20 minutes before starting the calibration.

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3.4.2.5.1. The restrictor valve shall be reset to a more restricted condition in increments of pump inlet depression (about 1 kPa) that will yield a minimum of six data points for the total calibration. The system shall be allowed to stabilize for 3 minutes before the data acquisition is repeated.

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3.4.2.5.2. The air flow rate (Q_s) at each test point shall be calculated in standard m^3/min from the flow meter data using the manufacturer's prescribed method.

3.4.2.5.3. The air flow rate shall then be converted to pump flow (V_0) in m^3/rev at absolute pump inlet temperature and pressure.

$$V_0 = \frac{Q_s}{n} \times \frac{T_p}{273.15\ K} \times \frac{101.325\ kPa}{P_p} \qquad (1)$$

where:

V_0 is the pump flow rate at T_p and P_p, m^3/rev;

Q_s is the air flow at 101.325 kPa and 273.15 K, m^3/min;

T_p is the pump inlet temperature, Kelvin (K);

P_p is the absolute pump inlet pressure, kPa;

n is the pump speed, min^{-1}.

3.4.2.5.4. 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 shall be calculated as follows:

$$x_0 = \frac{1}{n}\sqrt{\frac{\Delta P_p}{P_e}} \qquad (2)$$

where:

x_0 is the correlation function;

ΔP_p is the pressure differential from pump inlet to pump outlet, kPa;

P_e absolute outlet pressure ($PPO + P_b$), kPa.

A linear least-square fit is performed to generate the calibration equations having the following form:

$$V_0 = D_0 - M \times x_0 \qquad (3)$$

$$n = A - B \times \Delta P_p \qquad (4)$$

D_0,M, A and B are the slopes and intercepts describing the lines.

3.4.2.6. A CVS system having multiple speeds shall be calibrated at 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.

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3.4.2.7. The calculated values from the equation shall be within 0.5 per cent of the measured value of V_0. Values of M will vary from one pump to another. A calibration shall be performed at pump start-up and after major maintenance.

3.4.3. Calibration of a critical flow venturi (CFV)

3.4.3.1. Calibration of the CFV is based upon the flow equation for a critical venturi:

$$Q_s = \frac{K_v P}{\sqrt{T}} \qquad (5)$$

where:

Q_s is the flow, m³/min;

K_v is the calibration coefficient;

P is the absolute pressure, kPa;

T is the absolute temperature, Kelvin (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.

3.4.3.2. Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given:

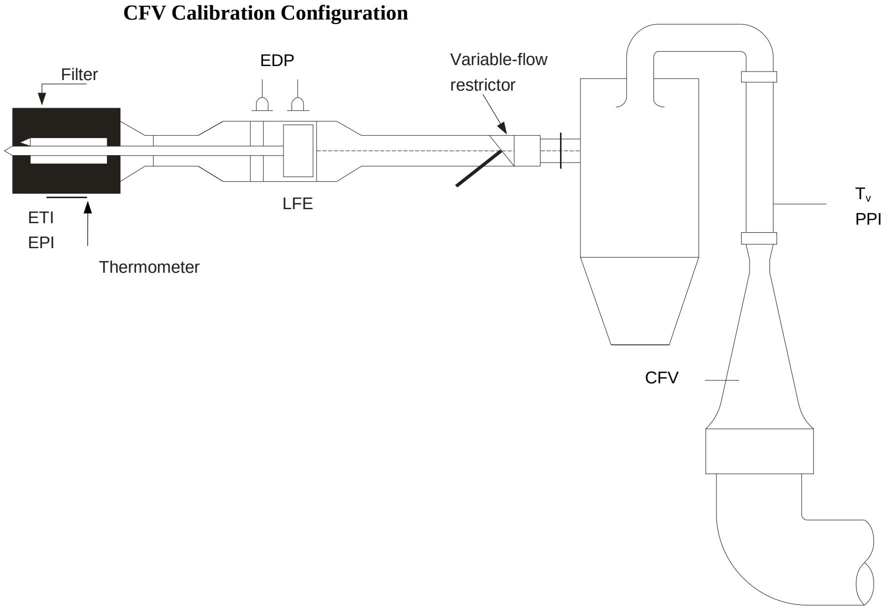
Barometric pressure (corrected) (P_b)	± 0.03 kPa,
LFE air temperature, flow meter (ETI)	± 0.15 K,
Pressure depression upstream of LFE (EPI)	± 0.01 kPa,
Pressure drop across LFE matrix (EDP)	± 0.0015 kPa,
Air flow (Q_s)	± 0.5 per cent,
CFV inlet depression (PPI)	± 0.02 kPa,

Temperature at venturi inlet (T_v) ± 0.2 K.

3.4.3.3. The equipment shall be set up as shown in Figure A5/7 and checked for leaks. Any leaks between the flow-measuring device and the critical flow venturi will seriously affect the accuracy of the calibration and shall therefore be prevented.

Figure A5/7

CFV Calibration Configuration



3.4.3.3.1. The variable-flow restrictor shall be set to the open position, the suction device shall be started and the system stabilized. Data from all instruments shall be recorded.

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3.4.3.3.2. The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.

3.4.3.3.3. The data recorded during the calibration shall be used in the following calculation:

3.4.3.3.3.1. The air flow rate (Q_s) at each test point shall be calculated from the flow meter data using the manufacturer's prescribed method.

Calculate values of the calibration coefficient for each test point:

$$K_v = \frac{Q_s \sqrt{T_v}}{P_v} \quad (6)$$

where:

Q_s is the flow rate, m^3/min at 273.15 K and 101.325, kPa;

T_v is the temperature at the venturi inlet, Kelvin (K);

P_v is the absolute pressure at the venturi inlet, kPa

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3.4.3.3.3.2. K_v shall be plotted as a function of venturi inlet pressure. For sonic flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases. These values of K_v shall not be used for further calculations.

3.4.3.3.3.3. For a minimum of eight points in the critical region, an average K_v and the standard deviation shall be calculated.

3.4.3.3.3.4. If the standard deviation exceeds 0.3 per cent of the average K_v, corrective action must be taken.

3.4.4. Calibration of a subsonic venturi (SSV)

3.4.4.1. Calibration of the SSV is based upon the flow equation for a subsonic venturi. Gas flow is a function of inlet pressure and temperature, and the pressure drop between the SSV inlet and throat.

3.4.4.2. Data analysis

3.4.4.2.1. The airflow rate (Q_{SSV}) at each restriction setting (minimum 16 settings) shall be calculated in standard m^3/s from the flow meter data using the manufacturer's prescribed method. The discharge coefficient, C_d, shall be calculated from the calibration data for each setting as follows:

$$C_d = \frac{Q_{SSV}}{d_V^2 \times p_p \times \sqrt{\left\{\frac{1}{T} \times \left(r_p^{1.426} - r_p^{1.713}\right) \times \left(\frac{1}{1 - r_D^4 \times r_p^{1.426}}\right)\right\}}} \qquad (7)$$

where:

Q_{SSV} is the airflow rate at standard conditions (101.325 kPa, 273.15 K), m^3/s;

T is the temperature at the venturi inlet, Kelvin (K);

d_V is the diameter of the SSV throat, m;

r_p is the ratio of the SSV throat to inlet absolute static pressure, $1 - \frac{\Delta p}{p_p}$;

r_D is the ratio of the SSV throat diameter, d_V, to the inlet pipe inner diameter D,

C_d is the discharge coefficient of the SSV

p_p is the absolute pressure at venturi inlet, kPa

To determine the range of subsonic flow, C_d shall be plotted as a function of Reynoldsnumber Re, at the SSV throat. The Re at the SSV throat shall be calculated with the following equation:

$$Re = A_1 \times \frac{Q_{SSV}}{d_V \times \mu} \qquad (8)$$

where:

$$\mu = \frac{b \times T^{1.5}}{S + T} \qquad (9)$$

A_1 is 25.55152 in SI, $\left(\frac{1}{m^3}\right)\left(\frac{min}{s}\right)\left(\frac{mm}{m}\right)$;

Q_{SSV} is the airflow rate at standard conditions (101.325 kPa, 273.15 K), m^3/s;

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d_V is the diameter of the SSV throat, m;

μ is the absolute or dynamic viscosity of the gas, kg/ms;

b is 1.458×10^6 (empirical constant), kg/ms $K^{0.5}$;

S is 110.4 (empirical constant), Kelvin (K).

3.4.4.2.2. Because Q_{SSV} is an input to the Re equation, the calculations must be started with an initial guess for Q_{SSV} or C_d of the calibration venturi, and repeated until Q_{SSV} converges. The convergence method shall be accurate to 0.1 per cent or better.

3.4.4.2.3. For a minimum of sixteen points in the region of subsonic flow, the calculated values of C_d from the resulting calibration curve fit equation must be within ± 0.5 per cent of the measured C_d for each calibration point.

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3.4.5. Calibration of an ultrasonic flow meter (UFM)

3.4.5.1. The UFM must be calibrated against a suitable reference flow meter.

3.4.5.2. The UFM must be calibrated in the CVS configuration which will be used in the test cell (diluted exhaust piping, suction device) and checked for leaks (see Figure A5/8).

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3.4.5.3. A heater shall be installed to condition the calibration flow in the event that the UFM system does not include a heat exchanger.

3.4.5.4. For each CVS flow setting that will be used, the calibration shall be performed at temperatures from room temperature to the maximum that will be experienced during vehicle testing.

3.4.5.5. The manufacturer's recommended procedure shall be followed for calibrating the electronic portions of the UFM.

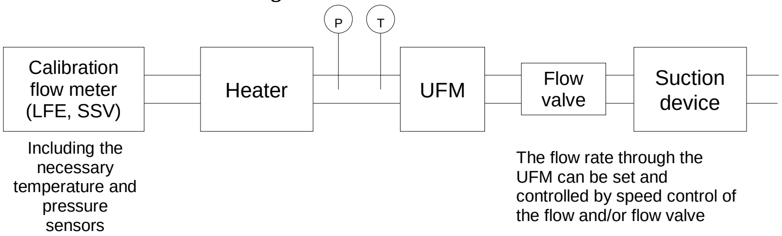
3.4.5.6. Measurements for flow calibration of the ultrasonic flow meter are required and the following data (in the case of the use of a laminar flow element) shall be found within the limits of precision given:

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 per cent,
UFM inlet depression (P_{act})	± 0.02 kPa,
Temperature at UFM inlet (T_{act})	± 0.2 K.

3.4.5.7. Procedure

3.4.5.7.1. The equipment shall be set up as shown in Figure A5/8 and checked for leaks. Any leaks between the flow-measuring device and the UFM will seriously affect the accuracy of the calibration.

Figure A5/8
USM Calibration Configuration



3.4.5.7.2. The suction device shall be started. The suction device speed and/or the flow valve should be adjusted to provide the set flow for the validation and the system stabilised. Data from all instruments shall be recorded.

3.4.5.7.3. For UFM systems without heat exchanger, the heater shall be operated to increase the temperature of the calibration air, allowed to stabilise and data from all the instruments recorded. The temperature shall be increased in reasonable steps until the maximum expected diluted exhaust temperature expected during the emissions test is reached.

3.4.5.7.4. The heater shall then be turned off and the suction device speed and/or flow valve shall be adjusted to the next flow setting that might be used for vehicle emissions testing after which the calibration sequence shall be repeated.

3.4.5.8. The data recorded during the calibration shall be used in the following calculations. The air flow rate (Q_s) at each test point is calculated from the flow meter data using the manufacturer's prescribed method.

$$K_v = \frac{Q_{reference}}{Q_s} \qquad (10)$$

where:

Q_s is the air flow rate at standard conditions (101.325 kPa, 273.15 K), m^3/s;

$Q_{reference}$ is the air flow rate of the calibration flow meter at standard conditions (101.325 kPa, 273.15 K), m^3/s;

K_v is the calibration coefficient.

For UFM systems without a heat exchanger, K_v shall be plotted as a function of T_{act}.

The maximum variation in K_v shall not exceed 0.3 per cent of the mean K_v value of all the measurements taken at the different temperatures.

3.5. System verification procedure

3.5.1. General requirements

3.5.1.1. The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of an emissions gas compound into the system whilst it is being operated as if during a normal test and subsequently analysing and calculating the emission gas compounds according to the equations of Sub-Annex 7 except that the density of propane shall be taken as 1.967 grams per litre at standard conditions. The CFO

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(paragraph 3.5.1.1.1. of this Sub-Annex) and gravimetric methods (paragraph 3.5.1.1.2. of this Sub-Annex) are known to give sufficient accuracy.

The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured is 2 per cent.

3.5.1.1.1. Critical flow orifice (CFO) method

The CFO method meters a constant flow of pure gas (CO, CO_2, or C_3H_8) using a critical flow orifice device.

3.5.1.1.1.1. A known quantity of pure gas (CO, CO_2 or C_3H_8) shall be fed into the CVS system through the calibrated critical orifice. If the inlet pressure is high enough, the flow rate (q), which is restricted by means of the critical flow orifice, is independent of orifice outlet pressure (critical flow). If deviations exceed 2 per cent, the cause of the malfunction shall be determined and corrected. The CVS system shall be operated as in a normal exhaust emission test and enough time shall be allowed for subsequent analysis. The gas collected in the sampling bag is analysed by the usual equipment and the results compared to the concentration of the gas samples which was known beforehand.

3.5.1.1.2. Gravimetric method

The gravimetric method weighs a limited quantity of pure gas (CO, CO_2, or C_3H_8).

3.5.1.1.2.1. The weight of a small cylinder filled with either pure carbon monoxide, carbon dioxide or propane shall be determined with a precision of ± 0.01 g. The CVS system shall operate as in a normal exhaust emission test while the pure gas is injected into the system for a time sufficient for subsequent analysis. The quantity of pure gas involved shall be determined by means of differential weighing. The gas accumulated in the bag shall be analysed by means of the equipment normally used for exhaust gas analysis. The results shall then be compared to the concentration figures computed previously.

4. Emissions measurement equipment

4.1. Gaseous emissions measurement equipment

4.1.1. System overview

4.1.1.1. A continuously proportional sample of the diluted exhaust gases and the dilution air shall be collected for analysis.

4.1.1.2. Mass of 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 into account the respective compound concentrations in dilution air.

4.1.2. Sampling system requirements

4.1.2.1. The sample of diluted exhaust gases shall be taken upstream from the suction device.

4.1.2.1.1. With the exception of paragraph 4.1.3.1. (hydrocarbon sampling system), paragraph 4.2. (particulate mass emissions measurement equipment) and paragraph 4.3. (particle number emissions measurement equipment) of this Sub-Annex, the dilute exhaust gas sample may be taken downstream of the conditioning devices (if any).

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4.1.2.2. The bag sampling flow rate shall be set to provide sufficient volumes of dilution air and diluted exhaust in the CVS bags to allow concentration measurement and shall not exceed 0.3 per cent of the flow rate of the dilute exhaust gases, unless the diluted exhaust bag fill volume is added to the integrated CVS volume.

4.1.2.3. A sample of the dilution air shall be taken near the dilution air inlet (after the filter if one is fitted).

4.1.2.4. The dilution air sample shall not be contaminated by exhaust gases from the mixing area.

4.1.2.5. The sampling rate for the dilution air shall be comparable to that used for the dilute exhaust gases.

4.1.2.6. The materials used for the sampling operations shall be such as not to change the concentration of the emissions compounds.

4.1.2.7. Filters may be used in order to extract the solid particles from the sample.

4.1.2.8. Any valve used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

4.1.2.9. Quick-fastening, gas-tight connections may be used between 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 analyser (three-way stop valves, for example).

4.1.2.10. Sample storage

4.1.2.10.1. The gas samples shall be collected in sampling bags of sufficient capacity not to impede the sample flow.

4.1.2.10.2. 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 per cent after 30 minutes (e.g.: laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

4.1.3. Sampling systems

4.1.3.1. Hydrocarbon sampling system (heated flame ionisation detector (HFID))

4.1.3.1.1. The hydrocarbon sampling system shall consist of a heated sampling probe, line, filter and pump. The sample shall be taken upstream of the heat exchanger (if fitted). 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.

4.1.3.1.2. All heated parts shall be maintained at a temperature of 463 K (190 °C) ± 10 K by the heating system.

4.1.3.1.3. The average concentration of the measured hydrocarbons shall be determined by integration of the second-by-second data divided by the phase or test duration.

4.1.3.1.4. The heated sampling line shall be fitted with a heated filter (F_H) having a 99 per cent efficiency for particles ≥ 0.3 µm to extract any solid particles from the continuous flow of gas required for analysis.

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4.1.3.1.5. The sampling system delay time (from the probe to the analyser inlet) shall be no more than 4 seconds.

4.1.3.1.6. The HFID shall be used with a constant mass flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

4.1.3.2. NO or NO_2 sampling system (if applicable)

4.1.3.2.1. A continuous sample flow of diluted exhaust gas shall be supplied to the analyser.

4.1.3.2.2. The average concentration of the NO or NO_2 shall be determined by integration of the second-by-second data divided by the phase or test duration.

4.1.3.2.3. The continuous NO or NO_2 measurement shall be used with a constant flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

4.1.4. Analysers

4.1.4.1. General requirements for gas analysis

4.1.4.1.1. The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample compounds.

4.1.4.1.2. If not defined otherwise, measurement errors shall not exceed ± 2 per cent (intrinsic error of analyser) disregarding the reference value for the calibration gases.

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4.1.4.1.3. The ambient air sample shall be measured on the same analyser with the same range.

4.1.4.1.4. No gas drying device shall be used before the analysers unless it is shown to have no effect on the content of the compound in the gas stream.

4.1.4.2. Carbon monoxide (CO) and carbon dioxide (CO_2) analysis

4.1.4.2.1. Analysers shall be of the non-dispersive infrared (NDIR) absorption type.

4.1.4.3. Hydrocarbons (HC) analysis for all fuels other than diesel fuel

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4.1.4.3.1. The analyser shall be of the flame ionization (FID) type calibrated with propane gas expressed in equivalent carbon atoms (C_1).

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4.1.4.4. Hydrocarbons (HC) analysis for diesel fuel and optionally for other fuels

4.1.4.4.1. The analyser shall be of the heated flame ionization type with detector, valves, pipework, etc., heated to 463 K (190 °C) ±10 K. It shall be calibrated with propane gas expressed equivalent to carbon atoms (C_1).

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4.1.4.5. Methane (CH_4) analysis

4.1.4.5.1. The analyser shall be either a gas chromatograph combined with a flame ionization detector (FID), or a flame ionization detector (FID) with a non-methane cutter, calibrated with methane or propane gas expressed equivalent to carbon atoms (C_1).

4.1.4.6. Nitrogen oxide (NO_x) analysis

4.1.4.6.1. The analysers shall be of chemiluminescent (CLA) or non-dispersive ultra-violet resonance absorption (NDUV) types.

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4.1.4.7. Nitrogen oxide (NO) analysis (where applicable)

4.1.4.7.1. The analysers shall be of chemiluminescent (CLA) or non-dispersive ultra-violet resonance absorption (NDUV) types.

4.1.4.8. Nitrogen dioxide (NO_2) analysis (where applicable)

4.1.4.8.1. Measurement of NO from continuously diluted exhausts

4.1.4.8.1.1. A CLA analyser may be used to measure the NO concentration continuously from diluted exhaust.

4.1.4.8.1.2. The CLA analyser shall be calibrated (zero/calibrated) in the NO mode using the NO certified concentration in the calibration gas cylinder with the NO_x converter bypassed (if installed).

4.1.4.8.1.3. The NO_2 concentration shall be determined by subtracting the NO concentration from the NO_x concentration in the CVS sample bags.

4.1.4.8.2. Measurement of NO_2 from continuously diluted exhausts

4.1.4.8.2.1. A specific NO_2 analyser (NDUV, QCL) may be used to measure the NO_2 concentration continuously from diluted exhaust.

4.1.4.8.2.2. The analyser shall be calibrated (zeroed/ calibrated) in the NO_2 mode using the NO_2 certified concentration in the calibration gas cylinder.

4.1.4.9. Nitrous oxide (N_2O) analysis with GC-ECD (where applicable)

4.1.4.9.1. A gas chromatograph with an electron-capture detector (GC–ECD) may be used to measure N_2O concentrations of diluted exhaust by batch sampling from exhaust and ambient bags. Refer to paragraph 7.2. of this Sub-Annex.

4.1.4.10. Nitrous oxide (N_2O) analysis with IR-absorption spectrometry (where applicable)

The analyser shall be a laser infrared spectrometer defined as modulated high resolution narrow band infrared analyser. An NDIR or FTIR may also be used but water, CO and CO_2 interference must be taken into consideration.

4.1.4.10.1. If the analyser shows interference to compounds present in the sample, this interference shall be corrected. Analysers must have combined interference that is within 0.0 ± 0.1 ppm.

4.1.5. Recommended system descriptions

4.1.5.1. Figure A5/9 is a schematic drawing of the gaseous emissions sampling system.

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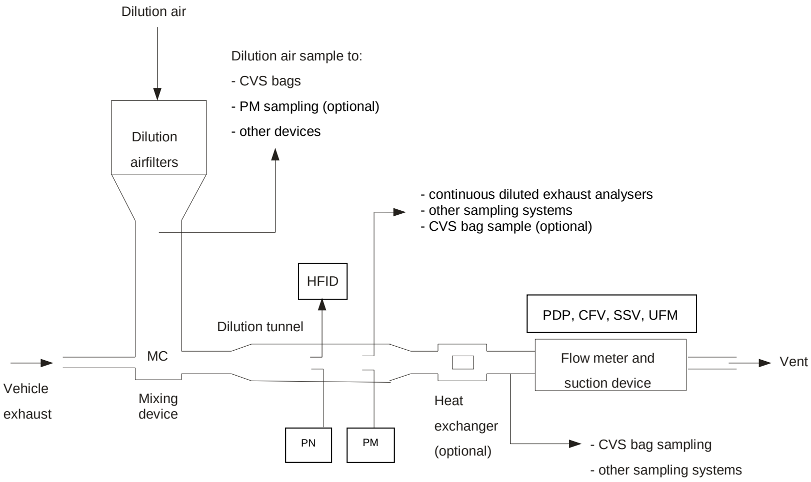
Figure A5/9

Full Flow Exhaust Dilution System Schematic



4.1.5.2. Examples of system components are as listed below.

Comment [RCG101]: Updated in 230414 GTR benchmark

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4.1.5.2.1. Two sampling probes for continuous sampling of the dilution air and of the diluted exhaust gas/air mixture.

4.1.5.2.2. A filter to extract solid particles from the flows of gas collected for analysis.

4.1.5.2.3. Pumps and flow controller to ensure a constant uniform flow of diluted exhaust gas and dilution air samples taken during the course of the test from sampling probes 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.

4.1.5.2.4. Quick-acting valves to divert a constant flow of gas samples into the sampling bags or to the outside vent.

4.1.5.2.5. Gas-tight, quick-lock coupling elements 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).

4.1.5.2.6. Bags for collecting samples of the diluted exhaust gas and of the dilution air during the test.

4.1.5.2.7. A sampling critical flow venturi to take proportional samples of the diluted exhaust gas (CFV-CVS only).

4.1.5.3. Additional components required for hydrocarbon sampling using a heated flame ionization detector (HFID) as shown in Figure A5/10 below.

4.1.5.3.1. Heated sample probe in the dilution tunnel located in the same vertical plane as the PM and PN sample probes.

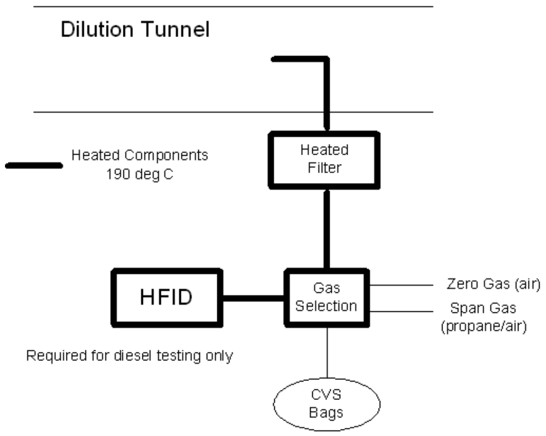
4.1.5.3.2. Heated filter located after the sampling point and before the HFID.

4.1.5.3.3. Heated selection valves between the zero/calibration gas supplies and the HFID.

4.1.5.3.4. Means of integrating and recording instantaneous hydrocarbon concentrations.

4.1.5.3.5. Heated sampling lines and heated components from the heated probe to the HFID.

Figure A5/10
Components required for hydrocarbon sampling using an HFID



4.2. Particulate mass emissions measurement equipment

4.2.1. Specification

4.2.1.1. System overview

4.2.1.1.1. The particulate sampling unit shall consist of a sampling probe (PSP) located in the dilution tunnel, a particle transfer tube (PTT), a filter holder(s) (FH), pump(s), flow rate regulators and measuring units. See Figures A5/11 and A5/12.

4.2.1.1.2. A particle size pre-classifier (PCF) (e.g. cyclone or impactor) may be used. In such case, it is recommended that it be employed upstream of the filter holder. However, a sampling probe, acting as an appropriate size-classification device such as that shown in Figure A5/13, is acceptable.

4.2.1.2. General requirements

4.2.1.2.1. The sampling probe for the test gas flow for particulates shall be so arranged within the dilution tunnel that a representative sample gas flow can be taken from the homogeneous air/exhaust mixture and shall be upstream of a heat exchanger (if any).

4.2.1.2.2. The particulate sample flow rate shall be proportional to the total mass flow of diluted exhaust gas in the dilution tunnel to within a tolerance of ± 5 per cent of the particulate sample flow rate. The verification of the proportionality of the PM sampling should be made during the commissioning of the system and as required by the approval authority.

4.2.1.2.3. The sampled dilute exhaust gas shall be maintained at a temperature above 293 K (20 °C) and below 325 K (52 °C) within 20 cm upstream or

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downstream of the particulate filter face. Heating or insulation of components of the PM sampling system to achieve this is permissible.

In the event that the 325 K (52 °C) limit is exceeded during a test where periodic regeneration event does not occur, the CVS flow rate should be increased or double dilution should be applied (assuming that the CVS flow rate is already sufficient so as not to cause condensation within the CVS, sample bags or analytical system).

4.2.1.2.4. The particulate sample shall be collected on a single filter mounted within a holder in the sampled dilute exhaust gas flow.

4.2.1.2.5. 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 minimise 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.

4.2.1.2.6. 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 paragraphs 3.3.5.1. or 3.3.6.4.2. above, so as to ensure that the flow rate in the system is constant and the sampling rate accordingly proportional.

4.2.1.2.7. Temperatures required for the PM mass measurement shall be measured with an accuracy of ± 1 °C and a response time ($t_{10} - t_{90}$) of 15 seconds or less.

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4.2.1.2.8. The PM sample flow from the dilution tunnel shall be measured with an accuracy of ± 2.5 per cent of reading or ± 1.5 per cent full scale, whichever is the least.

The above accuracy of the PM sample flow from the CVS tunnel is also applicable where double dilution is used. Consequently, the measurement and control of the secondary dilution air flow and diluted exhaust flow rates through the PM filter must be of a higher accuracy.

4.2.1.2.9. All data channels required for the PM mass measurement shall be logged at a frequency of 1 Hz or faster. Typically these would include:

(a) Diluted exhaust temperature at the PM filter;

(b) PM sampling flow rate;

(c) PM secondary dilution air flow rate (if secondary dilution is used);

(d) PM secondary dilution air temperature (if secondary dilution is used).

4.2.1.2.10. For double dilution systems, the accuracy of the diluted exhaust transferred from the dilution tunnel, V_{ep} in the equation is not measured directly but determined by differential flow measurement:

$$V_{ep} = V_{set} - V_{ssd} \qquad (11)$$

where:

V_{ep} is the volume of diluted exhaust gas flowing through particulate filter under standard conditions;

V_{set} is the volume of the double diluted exhaust gas passing through the particulate collection filters;

V_{ssd} is the volume of secondary dilution air.

The accuracy of the flow meters used for the measurement and control of the double diluted exhaust passing through the particulate collection filters and for the measurement/control of secondary dilution air shall be sufficient so that the differential volume (V_{ep}) shall meet the accuracy and proportional sampling requirements specified for single dilution.

The requirement that no condensation of the exhaust gas should occur in the CVS dilution tunnel, diluted exhaust flow rate measurement system, CVS bag collection or analysis systems shall also apply in the case of double dilution systems.

4.2.1.2.11. Each flow meter used in a particulate sampling and double dilution system shall be subjected to a linearity verification as required by the instrument manufacturer.

Figure A5/11
Particulate Sampling System

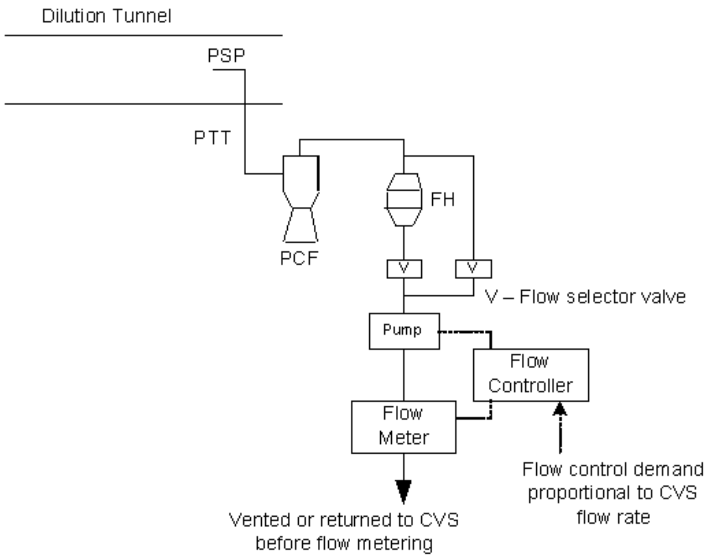
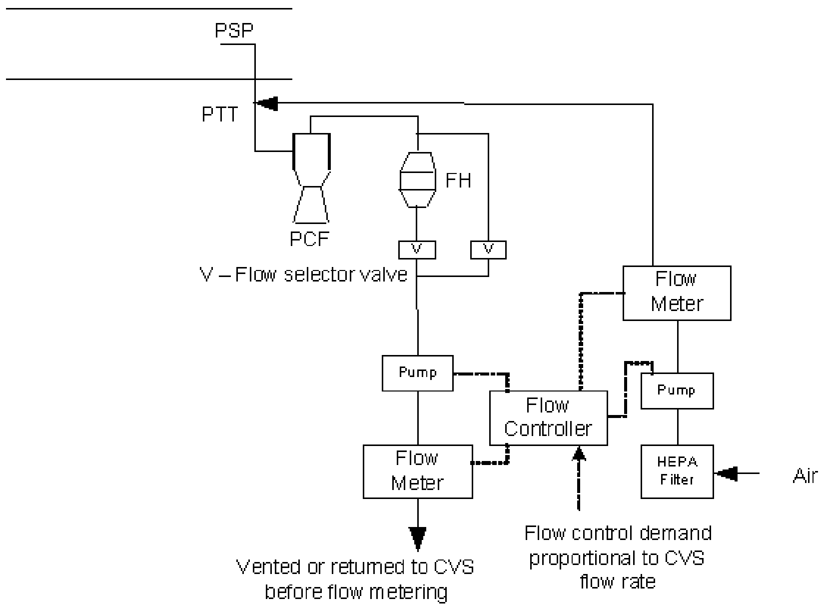


Figure A5/12
Double Dilution Particulate Sampling System



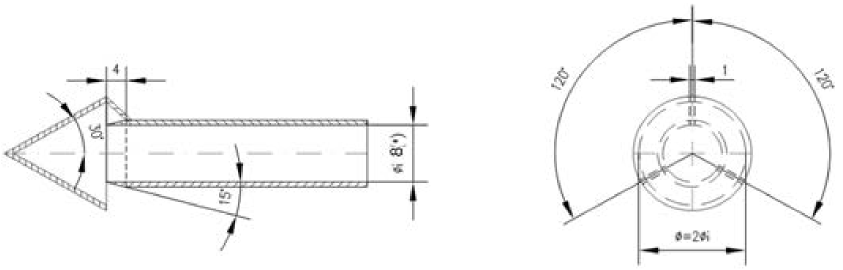
4.2.1.3. Specific requirements

4.2.1.3.1. PM sampling probe

4.2.1.3.1.1. The sample probe shall deliver the particle-size classification performance described in paragraph 4.2.1.3.1.4. below. 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 A5/13, may alternatively be used provided it achieves the pre-classification performance described in paragraph 4.2.1.3.1.4. below.

Comment [RCG102]: Update fro GTR

Figure A5/13
Alternative particulate sampling probe configuration



4.2.1.3.1.2. The sample probe shall be installed at least 10 tunnel diameters downstream of the exhaust gas inlet to the tunnel and have an internal diameter of at least 8 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 a spacing between probes of at least 5 cm.

4.2.1.3.1.3. The distance from the sampling tip to the filter mount shall be at least five probe diameters, but shall not exceed 2,000 mm.

4.2.1.3.1.4. The pre-classifier (e.g. cyclone, impactor, etc.) shall be located upstream of the filter holder assembly. The pre-classifier 50 per cent 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 per cent 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 A5/13, is acceptable as an alternative to a separate pre-classifier.

4.2.1.3.2. Particle transfer tube (PTT)

4.2.1.3.2.1. Any bends in the PTT shall be smooth and have the largest possible radii.

4.2.1.3.3. Secondary dilution

4.2.1.3.3.1. As an option, the sample extracted from the CVS for the purpose of PM measurement may be diluted at a second stage, subject to the following requirements:

4.2.1.3.3.1.1. Secondary dilution air shall be filtered through a medium capable of reducing particles in the most penetrating particle size of the filter material by ≥ 99.95 per cent, or through a HEPA filter of at least class H13 of

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EN 1822:2009. 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.

4.2.1.3.3.1.2. The secondary dilution air should be injected into the PTT as close to the outlet of the diluted exhaust from the dilution tunnel as possible.

4.2.1.3.3.1.3. The residence time from the point of secondary diluted air injection to the filter face shall be at least 0.25 seconds (s), but no longer than 5 seconds.

4.2.1.3.3.1.4. The diluted exhaust flow extracted from the dilution tunnel shall remain proportional to the CVS flow rate, as required for the single dilution method.

4.2.1.3.3.1.5. If the double diluted PM sample is returned to the CVS, the location of the sample return shall be selected so that it does not interfere with the extraction of other samples from the CVS.

4.2.1.3.4. Sample pump and flow meter

4.2.1.3.4.1. The sample gas flow measurement unit shall consist of pumps, gas flow regulators and flow measuring units.

4.2.1.3.4.2. The temperature of the gas flow in the flow meter may not fluctuate by more than ± 3 K except:

(a) When the PM sampling flow meter has real time monitoring and flow control operating at 1 Hz or faster;

(b) During regeneration tests on vehicles equipped with periodically regenerating after-treatment devices.

In addition, the sample mass flow rate shall remain proportional to the total flow of diluted exhaust gas to within a tolerance of ± 5 per cent 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 invalidated. When it is repeated, the rate of flow shall be decreased.

4.2.1.3.5. Filter and filter holder

4.2.1.3.5.1. A valve shall be located downstream of the filter in the direction of flow. The valve shall open and close within 1 second of the start and end of test.

4.2.1.3.5.2. For a given test, the gas filter face velocity shall be set to a single value within the range 20 cm/s to 105 cm/s and should be set at the start of the test so that 105 cm/s will not be exceeded when the dilution system is being operated with sampling flow proportional to CVS flow rate.

4.2.1.3.5.3. Fluorocarbon 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 per cent 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

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(c) Institute of Environmental Sciences and Technology, IEST-RP-CC021: Testing HEPA and ULPA Filter Media.

4.2.1.3.5.4. The filter holder assembly shall be of a design that provides an even flow distribution across the filter stain area. The filter shall be round and have a stain area of at least 1,075 mm^2.

4.2.2. Weighing chamber and analytical balance specifications

4.2.2.1. Weighing chamber conditions

(a) The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295 K ± 2 K (22 °C ± 2 °C, 22 °C ± 1 °C if possible) during all filter conditioning and weighing.

(b) Humidity shall be maintained to a dew point of less than 283.5 K (10.5 °C) and a relative humidity of 45 per cent ± 8 per cent.

(c) The levels of ambient contaminants in the chamber (or room) environment that would settle on the particulate filters during their stabilization shall be minimised. 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.

(d) During the weighing operation no deviations from the specified conditions are permitted.

4.2.2.2. Analytical balance

The analytical balance used to determine the filter weight shall meet the linearity verification criteria of Table A5/1 below. This implies a precision (standard deviation) of at least 2 µg and a resolution of at least 1 µg (1 digit = 1 µg).

Table A5/1
Analytical balance verification criteria

Measurement system	*Intercept b*	*Slope m*	*Standard error SEE*	*Coefficient of determination r^2*
PM Balance	≤ 1per cent max	0.99 – 1.01	≤ 1per cent max	≥ 0.998

4.2.2.3. Elimination of static electricity effects

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 neutraliser or a device of similar effect. Alternatively, nullification of static effects may be achieved through equalization of the static charge.

4.2.2.4. Buoyancy correction

The sample and reference filter weights shall be corrected for their buoyancy in air. The buoyancy correction is a function of sampling filter density, air density and the density of the balance calibration weight, and does not account for the buoyancy of the PM itself.

If the density of the filter material is not known, the following densities shall be used:

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(a) PTFE coated glass fibre filter: 2,300 kg/m^3;

(b) PTFE membrane filter: 2,144 kg/m^3;

(c) PTFE membrane filter with polymethylpentene support ring: 920 kg/m^3.

For stainless steel calibration weights, a density of 8,000 kg/m³ shall be used. If the material of the calibration weight is different, its density must be known. International Recommendation OIML R 111-1 Edition 2004(E) from International Organization of Legal Metrology on calibration weights should be followed.

The following equation shall be used:

$$m_f = m_{uncorr} \times \left(\frac{1-\frac{\rho_a}{\rho_w}}{1-\frac{\rho_a}{\rho_f}}\right) \quad (12)$$

where:

m_f is the corrected particulate sample mass, mg;

m_{uncorr} is the uncorrected particulate sample mass, mg;

ρ_a is the density of the air, kg/m^3;

ρ_w is the density of balance calibration weight, kg/m^3;

ρ_f is the density of the particulate sampling filter, kg/m^3.

The density of the air ρ_a shall be calculated as follows:

$$\rho_a = \frac{p_b \times M_{mix}}{R \times T_a} \quad (13)$$

p_b is the total atmospheric pressure, kPa;

T_a is the air temperature in the balance environment, Kelvin (K)

M_{mix} is the molar mass of air in a balanced environment, 28.836 g·mol^{-1}

R is the molar gas constant, 8.3144 J·mol^{-1}·K^{-1}

4.3. Particle number emissions measurement equipment

4.3.1. Specification

4.3.1.1. System overview

4.3.1.1.1. The particle sampling system shall consist of a probe or sampling point extracting a sample from a homogenously mixed flow in a dilution system, a volatile particle remover (VPR) upstream of a particle number counter (PNC) and suitable transfer tubing (see Figure A5/14).

4.3.1.1.2. 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 A5/13, is an acceptable alternative to the use of a particle size pre-classifier.

4.3.1.2. General requirements

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Deleted: $\rho_a = \frac{p_b \times 28.836}{8.3144 \times T_a}$
p_b is the total atmospheric pressure, kPa;
T_a is the air temperature in the balance environment, Kelvin (K).

Comment [SMD103]: 13.02.2014: modifications to the equation from M. Bergmann

Comment [RCG104]: Updated in 230414 GTR benchmark

4.3.1.2.1. The particle sampling point shall be located within a dilution system. In the case of double dilution systems, the particle sampling point shall be located within the primary dilution system.

4.3.1.2.1.1. The sampling probe tip or 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 of the VPR. The PTS shall meet the following conditions:

(a) The sampling probe shall be installed at least 10 tunnel diameters downstream of the exhaust gas inlet, facing upstream into the tunnel gas flow with its axis at the tip parallel to that of the dilution tunnel;

(b) The sampling probe shall be upstream of any conditioning device (e.g. heat exchanger);

(c) The sampling probe shall be positioned within the dilution tunnel so that the sample is taken from a homogeneous diluent/exhaust mixture.

4.3.1.2.1.2. Sample gas drawn through the PTS shall meet the following conditions:

(a) In the case of full flow exhaust dilution systems, it shall have a flow Reynolds number, Re, lower than 1,700;

(b) In the case of double dilution systems, it shall have a flow Reynolds number (Re) lower than 1,700 in the PTT i.e. downstream of the sampling probe or point;

(c) Shall have a residence time ≤ 3 seconds (s).

4.3.1.2.1.3. Any other sampling configuration for the PTS for which equivalent particle penetration at 30 nm can be demonstrated will be considered acceptable.

4.3.1.2.1.4. The outlet tube (OT) conducting the diluted sample from the VPR to the inlet of the PNC shall have the following properties:

(a) An internal diameter ≥ 4mm;

(b) A sample gas flow residence time of ≤ 0.8 seconds (s).

4.3.1.2.1.5. Any other sampling configuration for the OT for which equivalent particle penetration at 30 nm can be demonstrated will be considered acceptable.

4.3.1.2.2. The VPR shall include devices for sample dilution and for volatile particle removal.

4.3.1.2.3. 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.

4.3.1.2.4. 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.

4.3.1.3. Specific requirements

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4.3.1.3.1. The particle sample shall not pass through a pump before passing through the PNC.

4.3.1.3.2. A sample pre-classifier is recommended.

4.3.1.3.3. The sample preconditioning unit shall:

(a) 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;

(b) Include an initial heated dilution stage which outputs a sample at a temperature of ≥ 150 °C and ≤ 350 ± 10 °C, and dilutes by a factor of at least 10;

(c) Control heated stages to constant nominal operating temperatures, within the range ≥ 150 °C and ≤ 400 °C, to a tolerance of ± 10 °C;

(d) Provide an indication of whether or not heated stages are at their correct operating temperatures;

(e) Be designed to achieve a solid particle penetration efficiency of at least 70 per cent for particles of 100 nm electrical mobility diameter;

(f) Achieve a particle concentration reduction factor (($f_r(d_i)$), as calculated below, for particles of 30 nm and 50 nm electrical mobility diameters, that is no more than 30 per cent and 20 per cent respectively higher, and no more than 5 per cent lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole;

The particle concentration reduction factor at each particle size ($f_r(d_i)$) shall be calculated as follows:

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)} \qquad (14)$$

where:

$N_{in}(d_i)$ is the upstream particle number concentration for particles of diameter d_i;

$N_{out}(d_i)$ is the downstream particle number concentration for particles of diameter d_i;

d_i is the particle electrical mobility diameter (30, 50 or 100 nm).

$N_{in}(d_i)$ and $N_{out}(d_i)$ shall be corrected to the same conditions.

The mean particle concentration reduction, $\bar{f_r}$, at a given dilution setting shall be calculated as follows:

$$\bar{f_r} = \frac{f_r(30\ nm) + f_r(50\ nm) + f_r(100\ nm)}{3} \qquad (15)$$

It is recommended that the VPR is calibrated and validated as a complete unit;

(g) Be designed according to good engineering practice to ensure particle concentration reduction factors are stable across a test;

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Comment [RCG105]: EXPERT PROPOSAL: Paragraph approved by C. Hosier. Comments from other experts is requested.

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(h) Also achieve > 99.0 per cent 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.

4.3.1.3.4. The PNC shall:

(a) Operate under full flow operating conditions;

(b) Have a counting accuracy of ± 10 per cent 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;

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(c) Have a readability of at least 0.1 particles cm^{-3} at concentrations below 100 cm^{-3};

(d) Have a linear response to particle concentrations over the full measurement range in single particle count mode;

(e) Have a data reporting frequency equal to or greater than 0.5 Hz;

(f) Have a t_{90} response time over the measured concentration range of less than 5 seconds;

(g) Incorporate a coincidence correction function up to a maximum 10 per cent correction, and may make use of an internal calibration factor as determined in paragraph 5.7.1.3.of this Sub-Annex but shall not make use of any other algorithm to correct for or define the counting efficiency;

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(h) Have counting efficiencies at the different particle sized as specified in Table A5/2.

Table A5/2
Condensation Particle Counter (CPC) counting efficiency

Particle size electrical mobility diameter (nm)	*Condensation Particle Counter (CPC) counting efficiency(per cent)*
23 ± 1	50 ± 12
41 ± 1	> 90

4.3.1.3.5. If the PNC makes use of a working liquid, it shall be replaced at the frequency specified by the instrument manufacturer.

4.3.1.3.6. 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 shall be measured and recorded for the purposes of correcting particle concentration measurements to standard conditions.

4.3.1.3.7. The sum of the residence time of the PTS, VPR and OT plus the t_{90} response time of the PNC shall be no greater than 20 seconds.

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4.3.1.4. Recommended system description

The following paragraph contains the recommended practice for measurement of particle number. However, systems meeting the performance specifications in paragraphs 4.3.1.2. and 4.3.1.3. of this Sub-Annex are acceptable.

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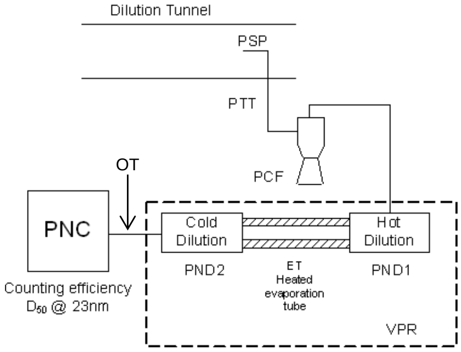
Figure A5/14

A recommended particle sampling system



4.3.1.4.1. Sampling system description

4.3.1.4.1.1. The particle sampling system shall consist of a sampling probe tip or particle sampling point in the dilution system, a particle transfer tube (PTT), a particle pre-classifier (PCF) and a volatile particle remover (VPR) upstream of the particle number counter (PNC) unit.

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4.3.1.4.1.2. The VPR shall include devices for sample dilution (particle number diluters: PND_1 and PND_2) and particle evaporation (evaporation tube, ET).

4.3.1.4.1.3. The sampling probe or sampling point for the test gas flow shall be so arranged within the dilution tunnel that a representative sample gas flow is taken from a homogeneous diluent/exhaust mixture.

4.3.1.4.1.4. The sum of the residence time of the system plus the t_{90} response time of the PNC shall be no greater than 20 seconds.

4.3.1.4.2. Particle transfer system (PTS)

The PTS shall fulfil the requirements of paragraph 4.3.1.2.1.1. of this Sub-Annex.

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4.3.1.4.3. Particle pre-classifier (PCF)

4.3.1.4.3.1. The recommended particle pre-classifier shall be located upstream of the VPR.

4.3.1.4.3.2. The pre-classifier 50 per cent cut point particle diameter shall be between 2.5 µm and 10 µm at the volumetric flow rate selected for sampling particle number emissions.

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4.3.1.4.3.3. The pre-classifier shall allow at least 99 per cent 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 particle number emissions.

4.3.1.4.4. Volatile particle remover (VPR)

4.3.1.4.4.1. 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.

4.3.1.4.4.2. The VPR shall provide an indication of whether or not PND_1 and the evaporation tube are at their correct operating temperatures.

4.3.1.4.4.3. The VPR shall achieve > 99.0 per cent 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.

4.3.1.4.4.4. The VPR shall be designed to achieve a solid particle penetration efficiency of at least 70 per cent for particles of 100 nm electrical mobility diameter.

4.3.1.4.4.5. The VPR shall also achieve a particle concentration reduction factor (fr) for particles of 30 nm and 50 nm electrical mobility diameters, that is no more than 30 per cent and 20 per cent respectively higher, and no more than 5 per cent lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole. It shall be designed according to good engineering practice to ensure particle concentration reduction factors are stable across a test.

4.3.1.4.5. First particle number dilution device (PND_1)

4.3.1.4.5.1. The first particle number dilution device shall be specifically designed to dilute particle number concentration and operate at a (wall) temperature of 150 °C to 350 °C.

4.3.1.4.5.1.1. The wall temperature set point should be held at a constant nominal operating temperature, within this range, to a tolerance of ± 10 °C and not exceed the wall temperature of the ET described in paragraph 4.3.1.4.6. of this Sub-Annex.

4.3.1.4.5.1.2. The diluter should be supplied with HEPA filtered dilution air and be capable of a dilution factor of 10 to 200.

4.3.1.4.6. Evaporation tube (ET)

4.3.1.4.6.1. 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 of 350 °C, to a tolerance of ± 10 °C.

4.3.1.4.6.2. The residence time within the ET shall be in the range 0.25 - 0.4 seconds (s).

4.3.1.4.7. Second particle number dilution device (PND_2)

4.3.1.4.7.1. 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.

4.3.1.4.7.2. 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.

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Comment [RCG106]: S.Dubuc has updated GTR to remove the word "times" – as it is not needed.

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Comment [RCG107]: EXPERT PROPOSAL: 350°C confirmed by C. Hosier. Comments from other experts is requested.

Comment [RCG108]: OPEN POINT: 28.04.2014: PM/PN experts are requested to clarify whether the "10 to 30" in paragraph 4.3.1.4. and the "10 and 15 " in paragraph 4.3.1.4.7.2. contradict each other.

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5. Calibration intervals and procedures

5.1. Calibration intervals

Table A5/3

Instrument calibration intervals

Instrument checks	*Interval*	*Criterion*
Gas analyser linearization (calibration)	Every 6 months	± 2 per cent of reading
Mid span	Every 6 months	± 2 per cent
CO NDIR: CO_2/H_2O interference	Monthly	-1 to 3 ppm
NO_x converter check	Monthly	> 95 per cent
CH_4 cutter check	Yearly	98 per cent of Ethane
FID CH_4 response	Yearly	See paragraph 5.4.3.
FID air/fuel flow	At major maintenance	According to instrument mfr.
NO/NO_2 NDUV: H_2O, HC interference	At major maintenance	According to instrument mfr.
Laser infrared spectrometers (modulated high resolution narrow band infrared analysers): interference check	Yearly or at major maintenance	According to instrument mfr.
GC methods	See paragraph 7.2.	See paragraph 7.2.
FTIR: linearity verification	Within 370 days before testing and after major maintenance	See paragraph 7.1.
Microgram balance linearity	Yearly or at major maintenance	See paragraph 4.2.2.2.
PNC (particle number counter)	See paragraph 5.7.1.1.	See paragraph 5.7.1.3.
VPR (volatile particle remover)	See paragraph 5.7.2.1.	See paragraph 5.7.2.

Table A5/4

Constant volume sampler (CVS) calibration intervals

CVS	*Interval*	*Criterion*
CVS flow	After overhaul	± 2 per cent
Dilution flow	Yearly	± 2 per cent
Temperature sensor	Yearly	± 1 °C
Pressure sensor	Yearly	± 0.4 kPa
Injection check	Weekly	± 2 per cent

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Table A5/5

Environmental data calibration intervals

Climate	*Interval*	*Criterion*
Temperature	Yearly	± 1 °C
Moisture dew	Yearly	± 5 per cent RH
Ambient pressure	Yearly	± 0.4 kPa
Cooling fan	After overhaul	According to paragraph 1.1.1.

5.2. Analyser calibration procedures

5.2.1. Each analyser shall be calibrated as specified by the instrument manufacturer or at least as often as described in Table A5/3.

5.2.2. Each normally used operating range shall be linearized by the following procedure:

5.2.2.1. The analyser linearization curve shall be established by at least five calibration points spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be not less than 80 per cent of the full scale.

5.2.2.2. The calibration gas concentration required may be obtained by means of a gas divider, diluting with purified N_2 or with purified synthetic air.

5.2.2.3. The linearization curve shall be 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.

5.2.2.4. The linearization curve shall not differ by more than ± 2 per cent from the nominal value of each calibration gas.

5.2.2.5. From the trace of the linearization curve and the linearization 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:

(a) Scale;

(b) Sensitivity;

(c) Zero point;

(d) Date of the linearization.

5.2.2.6. If it can be shown to the satisfaction of the approval authority that alternative technologies (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, these alternatives may be used.

5.3. Analyser zero and calibration verification procedure

5.3.1. Each normally used operating range shall be checked prior to each analysis in accordance with paragraphs 5.3.1.1. and 5.3.1.2.

5.3.1.1. The calibration shall be checked by use of a zero gas and by use of a calibration gas according to paragraph 1.2.14.2.3. of Sub-Annex 6.

5.3.1.2. After testing, zero gas and the same calibration gas shall be used for re-checking according to paragraph 1.2.14.2.4. of Sub-Annex 6.

Comment [RCG109]: NB: no x-ref in text

S.Dubuc has confirmed that the GTR will not have a x-ref

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Comment [RCG110]: Updated in 230414 GTR benchmark

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5.4. FID hydrocarbon response check procedure

5.4.1. Detector response optimization

The FID shall be adjusted as specified by the instrument manufacturer. Propane in air should be used on the most common operating range.

5.4.2. Calibration of the HC analyser

5.4.2.1. The analyser shall be calibrated using propane in air and purified synthetic air.

5.4.2.2. A calibration curve as described in paragraph 5.2.2.of this Sub-Annex shall be established.

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5.4.3. Response factors of different hydrocarbons and recommended limits

5.4.3.1. The response factor (R_f), for a particular hydrocarbon compound 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 per cent of full-scale deflection, for the operating range. The concentration shall be known to an accuracy of ± 2 per cent 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).

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5.4.3.2. Response factors shall be determined when introducing an analyser into service and at major service intervals thereafter. The test gases to be used and the recommended response factors are:

Methane and purified air: $1.00 < R_f < 1.15$

Propylene and purified air: $0.90 < R_f < 1.10$

Toluene and purified air: $0.90 < R_f < 1.10$

These are relative to a response factor (R_f) of 1.00 for propane and purified air.

5.5. NO_x converter efficiency test procedure

5.5.1. Using the test set up as shown in Figure A5/15 and the procedure described below, the efficiency of converters for the conversion of NO_2 into NO shall be tested by means of an ozonator as follows:

5.5.1.1. The analyser shall be calibrated in the most common operating range following the manufacturer's specifications using zero and calibration gas (the NO content of which shall amount to approximately 80 per cent of the operating range and the NO_2 concentration of the gas mixture shall be less than 5 per cent of the NO concentration). The NO_x analyser shall be in the NO mode so that the calibration gas does not pass through the converter. The indicated concentration shall be recorded.

5.5.1.2. Via a T-fitting, oxygen or synthetic air shall be added continuously to the calibration gas flow until the concentration indicated is approximately 10 per cent less than the indicated calibration concentration given in paragraph 5.5.1.1. above. The indicated concentration (c) shall be recorded. The ozonator shall be kept deactivated throughout this process.

5.5.1.3. The ozonator shall now be activated to generate enough ozone to bring the NO concentration down to 20 per cent (minimum 10 per cent) of the calibration concentration given in paragraph 5.5.1.1. above. The indicated concentration (d) shall be recorded.

5.5.1.4. The NO_x analyser shall then be switched to the NO_x mode, whereby the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. The indicated concentration (a) shall be recorded.

5.5.1.5. The ozonator shall now be deactivated. The mixture of gases described in paragraph 5.5.1.2. above shall pass through the converter into the detector. The indicated concentration (b) shall be recorded.

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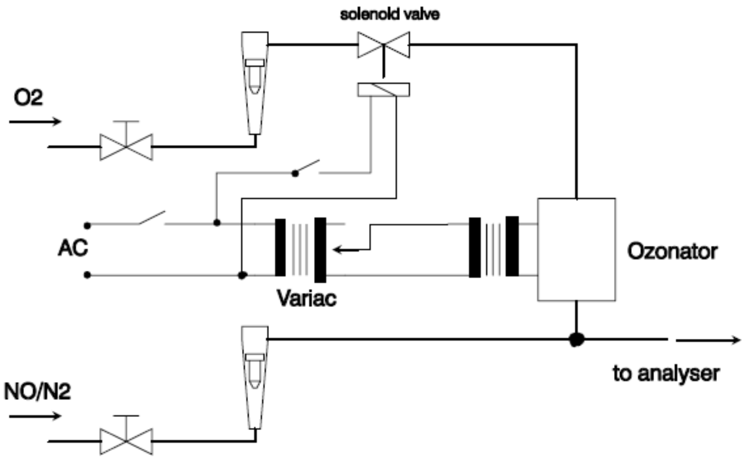
Figure A5/15
NO_x converter efficiency test configuration



5.5.1.6. With the ozonator deactivated, the flow of oxygen or synthetic air shall be shut off. The NO_2 reading of the analyser shall then be no more than 5 per cent above the figure given in paragraph 5.5.1.1. above.

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5.5.1.7. The per cent efficiency of the NO_x converter shall be calculated using the concentrations a, b, c and d determined in paragraphs 5.5.1.2. to 5.5.1.5. above as follows:

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$$\text{Efficiency} = \left(1 + \frac{a-b}{c-d}\right) \times 100 \qquad (16)$$

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5.5.1.7.1. The efficiency of the converter shall not be less than 95 per cent. The efficiency of the converter shall be tested in the frequency defined in Table A5/3.

5.6. Calibration of the microgram balance

5.6.1. The calibration of the microgram balance used for particulate filter weighing shall be traceable to a national or international standard. The balance shall comply with the linearity requirements given in paragraph 4.2.2.2.of this Sub-Annex. The linearity verification shall be performed at least every 12 months or whenever a system repair or change is made that could influence the calibration.

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5.7. Calibration and validation of the particle sampling system

Examples of calibration/validation methods are available at URL: http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/pmpFCP.html.

Comment [RCG112]: Editorial note. Hyperlink worked 5th Feb 2014

5.7.1. Calibration of the particle number counter

5.7.1.1. The approval authority shall ensure the existence of a calibration certificate for the PNC demonstrating compliance with a traceable standard within a 13-month period prior to the emissions test. Between calibrations, either the counting efficiency of the PNC should be monitored for deterioration, or the PNC wick should be routinely changed every 6 months (see Figures A5/16 and A5/17 below). PNC counting efficiency may be monitored against a reference PNC or against at least two other measurement PNCs. If the PNC reports particle concentrations within ± 10 per cent of the average of the concentrations from the reference PNC, or a group of two or more PNCs, then the PNC shall be considered stable, otherwise maintenance of the PNC is required. Where the PNC is monitored against two or more other measurement PNCs it is permissible to use a reference vehicle running sequentially in different test cells each with its own PNC.

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Figure A5/16
Nominal PNC Annual Sequence

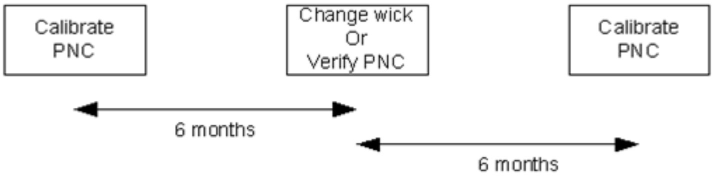
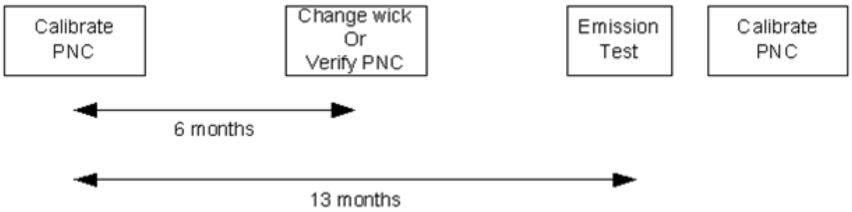


Figure A5/17
Extended PNC annual sequence (in the case where full PNC calibration is delayed)



5.7.1.2. The PNC shall also be recalibrated and a new calibration certificate issued following any major maintenance.

5.7.1.3. Calibration shall be traceable to a standard calibration method by comparing the response of the PNC under calibration with that of:

(a) A calibrated aerosol electrometer when simultaneously sampling electrostatically classified calibration particles; or

(b) A second PNC which has been directly calibrated by the above method.

5.7.1.3.1. In the case of paragraph 5.7.1.3.(a) above, calibration shall be undertaken using at least six standard concentrations spaced as uniformly as possible across the PNC's measurement range.

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5.7.1.3.2. In the case of paragraph 5.7.1.3.(b) above, calibration shall be undertaken using at least six standard concentrations across the PNC's measurement range. At least 3 points shall be at concentrations below 1,000 cm^{-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.

5.7.1.3.3. In the cases of paragraphs 5.7.1.3.(a) and 5.7.1.3.(b) above, the selected points shall 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 per cent 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 least squares 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).

5.7.1.4. Calibration shall also include a check, according to the requirements in paragraph 4.3.1.3.4.(h) of this Sub-Annex, 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.

5.7.2. Calibration/validation of the volatile particle remover

5.7.2.1. 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 particulate filter-equipped vehicles. The approval authority 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 13 month validation interval shall be permissible.

It is recommended that the VPR is calibrated and validated as a complete unit.

The VPR shall be characterised 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 per cent and 20 per cent higher respectively, and no more than 5 per cent 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 per cent of the mean particle concentration reduction factor ($\bar{f_r}$) determined during the primary calibration of the VPR.

5.7.2.2. 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 particles cm^{-3} at the VPR inlet. As an option, a polydisperse aerosol

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with an electrical mobility median diameter of 50 nm may be used for validation. The test aerosol shall be thermally stable at the VPR operating temperatures. Particle concentrations shall be measured upstream and downstream of the components.

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The particle concentration reduction factor for each monodisperse particle size ($f_r(d_i)$) shall be calculated as follows:

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)} \qquad (17)$$

where:

$N_{in}(d_i)$ is the upstream particle number concentration for particles of diameter d_i;

$N_{out}(d_i)$ is the downstream particle number concentration for particles of diameter d_i;

d_i is the particle electrical mobility diameter (30, 50 or 100 nm).

$N_{in}(d_i)$ and $N_{out}(d_i)$ shall be corrected to the same conditions.

The mean particle concentration reduction factor, $\bar{f_r}$, at a given dilution setting shall be calculated as follows:

$$\bar{f_r} = \frac{f_r(30nm) + f_r(50nm) + f_r(100nm)}{3} \qquad (18)$$

Where a polydisperse 50 nm aerosol is used for validation, the mean particle concentration reduction factor ($\bar{f_v}$) at the dilution setting used for validation shall be calculated as follows:

$$\bar{f_v} = \frac{N_{in}}{N_{out}} \qquad (19)$$

where:

N_{in} is the upstream particle number concentration;

N_{out} is the downstream particle number concentration.

5.7.2.3. A validation certificate for the VPR demonstrating effective volatile particle removal efficiency within a 6 month period prior to the emissions test shall be presented upon request. If the volatile particle remover incorporates temperature monitoring alarms, a 13 month validation interval shall be permissible.

5.7.2.3.1. The VPR shall demonstrate greater than 99.0 per cent removal of tetracontane ($CH_3(CH_2)_{38}CH_3$) particles of at least 30 nm electrical mobility diameter with an inlet concentration ≥ 10,000 cm^{-3} when operated at its minimum dilution setting and manufacturer's recommended operating temperature.

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5.7.3. Particle number system check procedures

5.7.3.1. On a monthly basis, the flow into the particle counter shall report a measured value within 5 per cent of the particle counter nominal flow rate when checked with a calibrated flow meter.

5.8. Accuracy of the mixing device

If a gas divider is used to perform the calibrations as defined in paragraph 5.2., the accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined to within ± 2 per cent. A calibration curve must be verified by a mid-span check as described in paragraph 5.3. A calibration gas with a concentration below 50 per cent of the analyser range shall be within 2 per cent of its certified concentration.

6. Reference gases

6.1. Pure gases

6.1.1. All values in ppm mean V-ppm (vpm)

6.1.2. The following pure gases shall be available, if necessary, for calibration and operation:

6.1.2.1. Nitrogen: (purity: ≤ 1 ppm C, ≤1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO, <0.1 ppm NO_2, <0.1 ppm N_2O, <0.1 ppm NH_3)

6.1.2.2. Synthetic air: (purity: ≤1 ppm C, ≤1 ppm CO, ≤400 ppm CO_2, ≤0.1 ppm NO); oxygen content between 18 and 21 per cent volume;

6.1.2.3. Oxygen: (purity: > 99.5 per cent vol. O_2);

6.1.2.4. Hydrogen (and mixture containing helium or nitrogen): (purity: ≤ 1 ppm C, ≤ 400 ppm CO_2);

6.1.2.5. Carbon monoxide: (minimum purity 99.5 per cent);

6.1.2.6. Propane: (minimum purity 99.5 per cent).

6.2. Calibration gases

6.2.1. The true concentration of a calibration gas shall be within ±1 per cent of the stated value or as given below.

Mixtures of gases having the following compositions shall be available with bulk gas specifications according to paragraphs 6.1.2.1. or 6.1.2.2. of this Sub-Annex:

(a) C_3H_8 in synthetic air (see paragraph 6.1.2.2. above);

(b) CO in nitrogen;

(c) CO_2 in nitrogen;

(d) CH_4 in synthetic air;

(e) NO in nitrogen (the amount of NO_2 contained in this calibration gas shall not exceed 5 per cent of the NO content);

(f) NO_2 in nitrogen (tolerance ± 2 per cent);

(g) N_2O in nitrogen (tolerance ± 2 per cent);

(h) C_2H_5OH in synthetic air or nitrogen (tolerance ± 2 per cent).

7. Additional sampling and analysis methods

7.1. Fourier transform infrared (FTIR) analyser

7.1.1. Measurement principle

7.1.1.1. An FTIR employs the broad waveband infrared spectroscopy principle. It allows simultaneous measurement of exhaust components whose standardized spectra are available in the instrument. The absorption spectrum

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(intensity/wavelength) is calculated from the measured interferogram (intensity/time) by means of the Fourier transform method.

7.1.1.2. The internal analyser sample stream up to the measurement cell and the cell itself shall be heated.

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7.1.1.3. Measurement cross interference

7.1.1.3.1. The spectral resolution of the target wavelength shall be within 0.5 cm^{-1} in order to minimize cross interference from other gases present in the exhaust gas.

7.1.1.3.2. Analyser response should not exceed ± 2 ppm at the maximum CO_2 and H_2O concentration expected during the vehicle test.

7.2. Sampling and analysis methods for N_2O

7.2.1. Gas chromatographic method

7.2.1.1. General description

Followed by the gas chromatographic separation, N_2O shall be analysed by an appropriate detector. This shall be an electron-capture detector (ECD).

7.2.1.2. Sampling

From each phase of the test, a gas sample shall be taken from the corresponding diluted exhaust bag and dilution air bag for analysis. A single composite dilution background sample can be analysed instead (not possible for phase weighing).

7.2.1.2.1. Sample transfer

Secondary sample storage media may be used to transfer samples from the test cell to the GC lab. Good engineering judgement shall be used to avoid additional dilution when transferring the sample from sample bags to secondary sample bags.

7.2.1.2.1.1. Secondary sample storage media.

Gas volumes shall be stored in sufficiently clean containers that off-gas minimally or allow permeation of gases. Good engineering judgment shall be used to determine acceptable thresholds of storage media cleanliness and permeation. In order to clean a container, it may be repeatedly purged, evacuated and heated.

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7.2.1.2.2. Sample storage

Secondary sample storage bags must be analysed within 24 hours and must be stored at room temperature.

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7.2.1.3. Instrumentation and apparatus

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7.2.1.3.1. A gas chromatograph with an electron-capture detector (GC-ECD) may be used to measure N_2O concentrations of diluted exhaust for batch sampling.

7.2.1.3.2. The sample may be injected directly into the GC, or an appropriate preconcentrator may be used. In case of preconcentration, this must be used for all necessary verifications and quality checks.

7.2.1.3.3. A packed or porous layer open tubular (PLOT) column phase of suitable polarity and length may be used to achieve adequate resolution of the N_2O peak for analysis.

7.2.1.3.4. Column temperature profile and carrier gas selection must be taken into consideration when setting up the method to achieve adequate N_2O peak resolution. Whenever possible, the operator must aim for baseline separated peaks.

7.2.1.3.5. Good engineering judgement shall be used to zero the instrument and to correct for drift.

Example: A calibration gas measurement may be performed before and after sample analysis without zeroing and using the average area counts of the pre-calibration and post-calibration measurements to generate a response factor (area counts/calibration gas concentration), which is then multiplied by the area counts from the sample to generate the sample concentration.

7.2.1.4. Reagents and material

All reagents, carrier and make up gases shall be of 99.995 per cent purity. Make up gas shall be N_2 or Ar/CH_4

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7.2.1.5. Peak integration procedure

7.2.1.5.1. Peak integrations are corrected as necessary in the data system. Any misplaced baseline segments are corrected in the reconstructed chromatogram.

7.2.1.5.2. Peak identifications provided by a computer shall be checked and corrected if necessary.

7.2.1.5.3. Peak areas shall be used for all evaluations. Peak heights may be used alternatively with approval of the approval authority.

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7.2.1.6. Linearity

A multipoint calibration to confirm instrument linearity shall be performed for the target compound:

(a) For new instruments;

(b) After doing instrument modifications that can affect linearity, and

(c) At least once per year.

7.2.1.6.1. The multipoint calibration consists of at least 3 concentrations, each above the limit of detection (LoD), distributed over the range of expected sample concentration.

7.2.1.6.2. Each concentration level is measured at least twice.

7.2.1.6.3. A linear least squares regression analysis is performed using concentration and average area counts to determine the regression correlation coefficient (r). The regression correlation coefficient must be greater than 0.995 to be considered linear for one point calibrations.

If the weekly check of the instrument response indicates that the linearity may have changed, a multipoint calibration must be done.

7.2.1.7. Quality control

7.2.1.7.1. The calibration standard shall be analysed each day of analysis to generate the response factors used to quantify the sample concentrations.

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7.2.1.7.2. A quality control standard shall be analysed within 24 hours before the analysis of the sample.

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7.2.1.8. Calculations

$$\text{Conc. } N_2O = \text{PeakArea}_{\text{sample}} \times \text{ResponseFactor}_{\text{sample}} \quad (20)$$

$$\text{ResponseFactor}_{\text{sample}} = \frac{\text{Concentration}_{\text{standard (ppb)}}}{\text{PeakArea}_{\text{standard}}} \quad (21)$$

7.2.1.9. Limit of detection, limit of quantification

The detection limit is based on the noise measurement close to the retention time of N_2O (reference DIN 32645, 01.11.2008):

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$$\text{Limit of Detection: LoD} = \text{avg. (noise)} + 3 \times \text{std. dev.} \quad (22)$$

where std. dev. is considered to be equal to noise.

$$\text{Limit of Quantification: LoQ} = 3 \times \text{LoD} \quad (23)$$

For the purpose of calculating the mass of N_2O, the concentration below LoD is considered to be zero.

7.2.1.10. Interference verification.

Interference is any component present in the sample with a retention time similar to that of the target compound described in this method. To reduce interference error, proof of chemical identity may require periodic confirmations using an alternate method or instrumentation.

Sub-Annex 6

Type 1 test procedure and test conditions

1. Test procedures and test conditions

1.1 Description of tests

1.1.1. The tests verify the emissions of gaseous compounds, particulate matter, particle number, CO_2 emissions, and fuel consumption, in a characteristic driving cycle.

1.1.1.1. The tests shall be carried out by the method described in paragraph 1.2. of this Sub-Annex. Gases, particulate matter and particle number shall be sampled and analysed by the prescribed methods.

1.1.1.2. The number of tests shall be determined as shown in Figure A6/1. R_{i1} to R_{i3} describe the final measurement results of three tests to determine gaseous compounds, particulate matter, particle number, CO_2 emissions, and fuel consumption where applicable. L are limit values as defined in Annex I of Regulation (EC) No 715/2007. If a vehicle configuration must be driven more than once to show compliance with emissions limits (as defined in Figure A6/1), the average CO_2 value must be calculated for type approval.

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Comment [RCG114]: Will need a x-ref to new Annex 10 which will include:

Supplemental Test for determination of CO2 emissions under representative regional conditions (provided by BMW/Audi)

and possibly some details on

Test cycle flexibilities – to be provided by TUG/TNO

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Comment [RCG115]: AdminWG 080514 – x-ref updated to include Annex I

Comment [RCG116]: AdminWG 040414 – confirmed that we need to refer to the limit tables in EC 715/2007.

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Comment [RCG117]: AdminWG 040414 – replace “regional” with “emissions”.

Figure A6/1

Flowchart for the number of Type 1 tests

Comment [RCG118]: Updated in 230414 GTR benchmark to change "*" to "x"

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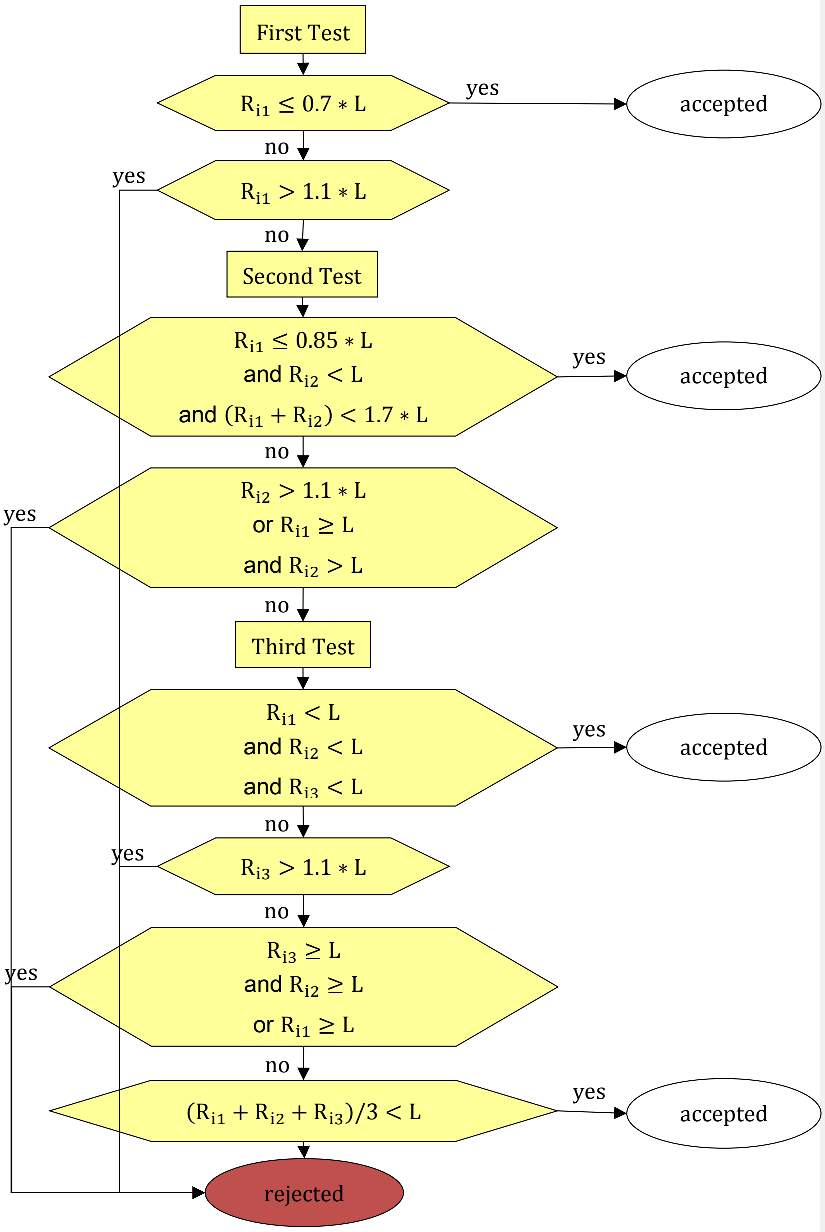

1.2. Type 1 test conditions

1.2.1. Overview

1.2.1.1. The Type 1 test shall consist of prescribed sequences of dynamometer preparation, fuelling, soaking, and operating conditions.

1.2.1.2. The Type 1 test shall consist of engine start-ups and vehicle operation on a chassis dynamometer on the applicable WLTC for the CO_2 vehicle family. A proportional part of the diluted exhaust emissions shall be collected continuously for subsequent analysis using a constant volume sampler.

1.2.1.3. Background concentrations shall be measured for all compounds for which dilute mass emissions measurements are conducted. For exhaust emission testing, this requires sampling and analysis of the dilution air.

1.2.1.3.1. Background particulate mass measurement

1.2.1.3.1.1. Where the manufacturer requests subtraction of either dilution air or dilution tunnel particulate matter background from emissions measurements, these background levels shall be determined according to the procedures listed in paragraphs 1.2.1.3.1.1.1. to 1.2.1.3.1.1.3.

1.2.1.3.1.1.1. The maximum permissible background correction shall be a mass on the filter equivalent to 1 mg/km at the flow rate of the test.

1.2.1.3.1.1.2. If the background exceeds this level, the default figure of 1 mg/km shall be subtracted.

1.2.1.3.1.1.3. Where subtraction of the background contribution gives a negative result, the particulate mass result shall be considered to be zero.

1.2.1.3.1.2. Dilution air particulate matter background level shall be determined by passing filtered dilution air through the particulate filter. This shall be drawn from a point immediately downstream of the dilution air filters. Background levels in µg/m^3 shall be determined as a rolling average of at least 14 measurements with at least one measurement per week.

1.2.1.3.1.3. Dilution tunnel particulate matter background level shall be determined by passing filtered dilution air through the particulate filter. This shall be drawn from the same point as the particulate matter sample. Where secondary dilution is used for the test, the secondary dilution system shall be active for the purposes of background measurement. One measurement may be performed on the day of test, either prior to or after the test.

1.2.1.3.2. Background particle number determination

1.2.1.3.2.1. Where the manufacturer requests a background correction, these background levels shall be determined as follows:

1.2.1.3.2.1.1. The background value can be calculated or measured. The maximum permissible background correction shall be related to the maximum allowable leak rate of the particle number measurement system (0.5 particles/cm³) scaled from the particle concentration reduction factor (PCRF) and the CVS flow rate used in the actual test;

1.2.1.3.2.1.2. Either the approval authority or the manufacturer can request that actual background measurements are used instead of calculated ones.

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Comment [RCG119]: Is this an option at EC / UNECE level?

Confirm whether to amend/delete.

AdminWG 040414 – To be discussed further with Type Approval measurement experts

AdminWG 080514 – text updated based on feedback from W.Coleman and colleagues.

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Deleted: the following subparagraphs.

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Comment [RCG120]: Is this an option at EC / UNECE level? Confirm whether to amend/delete.

AdminWG 040414 – To be discussed further with Type Approval measurement experts

AdminWG 080514 – text updated based on feedback from W.Coleman and colleagues.

Deleted: Contracting Party permits subtraction of either dilution air or dilution tunnel particle number background from emissions measurements or a

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Comment [RCG121]: Amend to "Member State"?

AdminWG 040414 – To be discussed further with Type Approval measurement experts

AdminWG 080514 – text updated based on feedback from W.Coleman and colleagues.

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1.2.1.3.2.1.3. Where subtraction of the background contribution gives a negative result, the particle number result shall be considered to be zero.

1.2.1.3.2.2. Dilution air particle number background level shall be determined by sampling filtered dilution air. This shall be drawn from a point immediately downstream of the dilution air filters into the particle number measurement system. Background levels in #/cm^3 shall be determined as a rolling average of least 14 measurements with at least one measurement per week.

1.2.1.3.2.3. Dilution tunnel particle number background level shall be determined by sampling filtered dilution air. This shall be drawn from the same point as the particle number sample. Where secondary dilution is used for the test the secondary dilution system should be active for the purposes of background measurement. One measurement may be performed on the day of test, either prior to or after the test using the actual PCRF and the CVS flow rate utilised during the test.

1.2.2. General test cell equipment

1.2.2.1. Parameters to be measured

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

(a) Test cell ambient air

(b) Dilution and sampling system temperatures as required for emissions measurement systems defined in Sub-Annex 5.

1.2.2.1.2. Atmospheric pressure shall be measurable with a resolution of ±0.1 kPa.

1.2.2.1.3. Specific humidity (H) shall be measurable with a resolution of ±1 g H_2O/kg dry air.

1.2.2.2. Test cell and soak area

1.2.2.2.1. Test cell

1.2.2.2.1.1. The test cell shall have a temperature set point of 296 K. The tolerance of the actual value shall be within ± 5 K. The air temperature and humidity shall be measured at the vehicle cooling fan outlet at a minimum of 1 Hz. For temperature at the start of the test, see paragraph 1.2.8.1. of this Sub-Annex.

1.2.2.2.1.2. The specific humidity (H) of either the air in the test cell or the intake air of the engine shall be such that:

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

1.2.2.2.1.3. Humidity shall be measured continuously at a minimum of 1 Hz.

1.2.2.2.2. Soak area

The soak area shall have a temperature set point of 296 K and the tolerance of the actual value shall be within ± 3 K on a 5 minute running average and shall not show a systematic deviation from the set point. The temperature shall be measured continuously at a minimum of 1 Hz.

1.2.3. Test vehicle

1.2.3.1. General

The test vehicle shall conform in all its components with the production series, or, if the vehicle is different from the production series, a full description shall be included in the test report. In selecting the test vehicle,

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Comment [RCG122]: The units for absolute humidity are incorrect. Need to update by replacing absolute humidity" with "specific humidity"

AdminWG 080514 – text updated to correct.

EXPERT PROPOSAL: 30.04.2014: Absolute humidity has the units of mass water/volume air and not of mass water/mass air. Absolute humidity has been replaced by specific humidity. Agreed by experts.

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Comment [RCG123]: The units for absolute humidity are incorrect. Need to update by replacing absolute humidity" with "specific humidity"

AdminWG 080514 – text updated to correct.

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the manufacturer and approval authority shall agree which vehicle model is representative for the CO_2 vehicle family. For the measurement of emissions the road load as determined with test vehicle H shall be applied. If at the request of the manufacturer the CO_2 interpolation method is used (see paragraph 3.2.3.2 of Sub-Annex 7), an additional measurement of emissions shall be performed with the road load as determined with test vehicle L. Both vehicle H and L shall be tested with the shortest final transmission ratio within the CO_2 vehicle family. The CO_2 interpolation method shall only be applied on those road load relevant characteristics that were chosen to be different between test vehicle L and test vehicle H; for the other road load relevant characteristic(s), the value of test vehicle H shall be applied in the CO_2 interpolation method. The manufacturer may also choose not to apply the interpolation method for road load relevant characteristics between test vehicles L and H; in that case the value of the test vehicle H shall be applied in the CO_2 interpolation method.

1.2.3.2. CO_2 interpolation range

The CO_2 interpolation method shall only be used if the difference in CO_2 between test vehicles L and H is between a minimum of 5 and a maximum of 30 g/km or 20 per cent of the CO_2 for vehicle H, whichever value is the lower.

At the request of the manufacturer, and with approval of the approval authority, the CO_2 interpolation line may be extrapolated to a maximum of 3 g/km above the CO_2 emission of vehicle H or below the CO_2 emission of vehicle L. This extension is only valid within the absolute boundaries of the interpolation range specified above.

1.2.3.3. Run-in

The vehicle must be presented in good technical condition. It must have been run-in and driven between 3,000 and 15,000 km before the test. The engine, transmission and vehicle shall be run-in in accordance with the manufacturer's recommendations.

1.2.4. Settings

1.2.4.1. Dynamometer settings and verification shall be performed according to Sub-Annex 4.

1.2.4.2. Dynamometer operation mode

1.2.4.2.1. Dynamometer operation mode can be activated at the manufacturer's request.

1.2.4.2.2. A dynamometer operation mode, if any, shall be activated by using the manufacturer's instruction (e.g. using vehicle steering wheel buttons in a special sequence, using the manufacturer's workshop tester, removing a fuse).

The manufacturer shall provide the approval authority a list of the deactivated devices and justification of the deactivation.

Auxiliaries shall be switched off or deactivated during dynamometer operation.

1.2.4.2.3. Dynamometer operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the emissions and fuel

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Comment [RCG124]: ACEA (W.Coleman proposal)

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consumption under the test conditions. Any device that affects the operation on a chassis dynamometer shall be set to ensure a proper operation.

Activation or deactivation of the mode shall be included in the test report.

1.2.4.3. The vehicle's exhaust system shall not exhibit any leak likely to reduce the quantity of gas collected.

1.2.4.4. The settings of the engine and of the vehicle's controls shall be those prescribed by the manufacturer.

1.2.4.5. Tyres shall be of a type specified as original equipment by the vehicle manufacturer. Tyre pressure may be increased by up to 50 per cent above the pressure specified in paragraph 4.2.2.3. of Sub-Annex 4. The same tyre pressure shall be used for the setting of the dynamometer and for all subsequent testing. The tyre pressure used shall be included in the test report.

1.2.4.6. Reference fuel

1.2.4.6.1. The appropriate reference fuel as defined in Sub-Annex 3 shall be used for testing.

1.2.4.7. Test vehicle preparation

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

1.2.4.7.2. If necessary, the manufacturer shall provide additional fittings and adapters, as required to accommodate a fuel drain at the lowest point possible in the tank(s) as installed on the vehicle, and to provide for exhaust sample collection.

1.2.5. Preliminary testing cycles

1.2.5.1. Preliminary testing cycles may be carried out if requested by the manufacturer to follow the speed trace within the prescribed limits.

1.2.6. Test vehicle preconditioning

1.2.6.1. The fuel tank or fuel tanks shall be filled with the specified test fuel. If the existing fuel in the fuel tank or fuel tanks does not meet the specifications contained in paragraph 1.2.4.6. above, the existing fuel shall be drained prior to the fuel fill. For the above operations, the evaporative emission control system shall neither be abnormally purged nor abnormally loaded.

1.2.6.2. Battery charging

Before the preconditioning test cycle, the batteries shall be fully charged. At the request of the manufacturer, charging may be omitted before preconditioning. The batteries shall not be charged again before official testing.

1.2.6.3. The test vehicle shall be moved to the test cell and the operations listed in the following sub-paragraphs shall be performed.

1.2.6.3.1. The test vehicle shall be placed, either by being driven or pushed, on a dynamometer and operated through the applicable WLTCs. The vehicle need not be cold, and may be used to set the dynamometer load.

1.2.6.3.2. The dynamometer load shall be set according to paragraphs 7. and 8. of Sub-Annex 4.

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1.2.6.3.3. During preconditioning, the test cell temperature shall be the same as defined for the Type 1 test (paragraph 1.2.2.2.1. of this Sub-Annex).

1.2.6.3.4. The drive-wheel tyre pressure shall be set in accordance with paragraph 1.2.4.5. of this Sub-Annex.

1.2.6.3.5. Between the tests on the first gaseous reference fuel and the second gaseous reference fuel, for positive ignition-engined vehicles fuelled with LPG or NG/biomethane or so equipped that they can be fuelled with either petrol or LPG or NG/biomethane, the vehicle shall be preconditioned again before the test on the second reference fuel.

1.2.6.3.6. For preconditioning, the applicable WLTC shall be driven. Starting the engine and driving shall be performed according to paragraph 1.2.6.4. of this Sub-Annex.

The dynamometer shall be set according to Annex 4.

1.2.6.3.7. At request of the manufacturer or approval authority, additional WLTCs may be performed in order to bring the vehicle and its control systems to a stabilized condition.

1.2.6.3.8. The extent of such additional preconditioning shall be included in the test report.

1.2.6.3.9. 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 preconditioning, that a 120 km/h steady state drive cycle of 20 minutes duration be driven by a low particulate emitting vehicle. Longer and/or higher speed running is permissible for sampling equipment preconditioning if required. Dilution tunnel background measurements, where applicable, shall be taken after the tunnel preconditioning running, and prior to any subsequent vehicle testing.

1.2.6.4. The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions.

The switch of the predominant mode to another available mode after the vehicle has been started shall only be possible by an intentional action of the driver having no impact on any other functionality of the vehicle.

1.2.6.4.1. If the vehicle does not start, the test is void, preconditioning tests must be repeated and a new test must be driven.

1.2.6.4.2. The cycle starts on the initiation of the engine start-up procedure.

1.2.6.4.3. In cases where LPG or NG/biomethane is used as a fuel, it is permissible that the engine is started on petrol and switched automatically to LPG or NG/biomethane after a predetermined period of time which cannot be changed by the driver.

1.2.6.4.4. During stationary/idling vehicle phases, the brakes shall be applied with appropriate force to prevent the drive wheels from turning.

1.2.6.4.5. During the test, speed shall be recorded against time or collected by the data acquisition system at a rate of no less than 1 Hz so that the actual driven speed can be assessed.

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Comment [RCG125]: NB: The paragraph has been amended following S.Dubuc consultation with an expert. 250314 e-mail.

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Comment [RCG126]: AdminWG 290414 – delete "by the approval authority". To be confirmed. AdminWG 080514 – to be agreed with Stephan Redmann & Helge Schmidt. 140514 – Helge Schmidt confirmed deletion

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1.2.6.4.6. The distance actually driven by the vehicle shall be recorded for each WLTC phase.

1.2.6.5. Use of the transmission

1.2.6.5.1. Manual shift transmission

The gear shift prescriptions described in Sub-Annex 2 shall be followed. Vehicles tested according to Sub-Annex 8 shall be driven according to paragraph 1.6. of that Sub-Annex.

Vehicles which cannot attain the acceleration and maximum speed values required in the applicable WLTC shall be operated with the accelerator control fully activated until they once again reach the required driving curve. Speed trace violations under these circumstances shall not void a test. Deviations from the driving cycle shall be included in the test report.

1.2.6.5.1.1. The tolerances given in paragraph 1.2.6.6. below shall apply.

1.2.6.5.1.2. The gear change must be started and completed within ± 1.0 second of the prescribed gear shift point.

1.2.6.5.1.3. The clutch must be depressed within ± 1.0 second of the prescribed clutch operating point.

1.2.6.5.2. Automatic shift transmission

1.2.6.5.2.1. Vehicles equipped with automatic shift transmissions shall be tested in the predominant drive mode. The accelerator control shall be used in such a way as to accurately follow the speed trace.

1.2.6.5.2.2. Vehicles equipped with automatic shift transmissions with driver-selectable modes shall fulfil the limits of criteria emissions in all automatic shift modes used for forward driving. The manufacturer shall give respective evidence to the approval authority. Provided the manufacturer can give technical evidence with the agreement of the approval authority, the dedicated driver-selectable modes for very special limited purposes shall not be considered (e.g. maintenance mode, crawler mode).

1.2.6.5.2.3. The manufacturer shall give evidence to the approval authority of the existence of a predominant mode that fulfils the requirements of paragraph 3.5.10. of this Annex. With the agreement of the approval authority, the predominant mode may be used as the only mode for the determination of criteria emissions, CO_2 emissions, and fuel consumption. Notwithstanding the existence of a predominant mode, the criteria emission limits shall be fulfilled in all considered automatic shift modes used for forward driving as described in paragraph 1.2.6.5.2.2. of this Sub-Annex.

1.2.6.5.2.4. If the vehicle has no predominant mode or the requested predominant mode is not agreed by the approval authority as a predominant mode, the vehicle shall be tested in the best case mode and worst case mode for criteria emissions, CO_2 emissions, and fuel consumption. Best and worst case modes shall be identified by the given evidence on the CO_2 emissions and fuel consumption in all modes. CO_2 emissions and fuel consumption shall be the average of the test results in both modes. Test results for both modes shall be included in the test report. Notwithstanding the usage of the best and worst case modes for testing, the criteria emission limits shall be fulfilled in all considered automatic shift modes used for forward driving as described in paragraph 1.2.6.5.2.2. of this Sub-Annex.

1.2.6.5.2.5. The tolerances given in paragraph 1.2.6.6. below shall apply.

After initial engagement, the selector shall not be operated at any time during the test. Initial engagement shall be done 1 second before beginning of the first acceleration.

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1.2.6.5.3. Use of multi-mode transmissions

1.2.6.5.3.1. In the case of emissions testing, emission standards shall be fulfilled in all modes.

1.2.6.5.3.2. In the case of CO_2/fuel consumption testing, the vehicle shall be tested in the predominant mode.

If the vehicle has no predominant mode, the vehicle shall be tested in the best case mode and worst case mode, and the CO_2 and fuel consumption results shall be the average of both modes.

Vehicles with an automatic transmission with a manual mode shall be tested according paragraph 1.2.6.5.2. of this Sub-Annex.

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1.2.6.6. Speed trace tolerances

The following tolerances shall be allowed between the indicated speed and the theoretical speed of the respective WLTC:

(a) The upper limit is 2.0 km/h higher than the highest point of the trace within ± 1.0 second of the given point in time;

(b) The lower limit is 2.0 km/h lower than the lowest point of the trace within ± 1.0 second of the given time.

See Figure A6/2.

Comment [RCG127]: Updated in 230414 GTR benchmark

Speed tolerances greater than those prescribed shall be accepted provided the tolerances are never exceeded for more than 1 second on any one occasion.

There shall be no more than ten such deviations per test.

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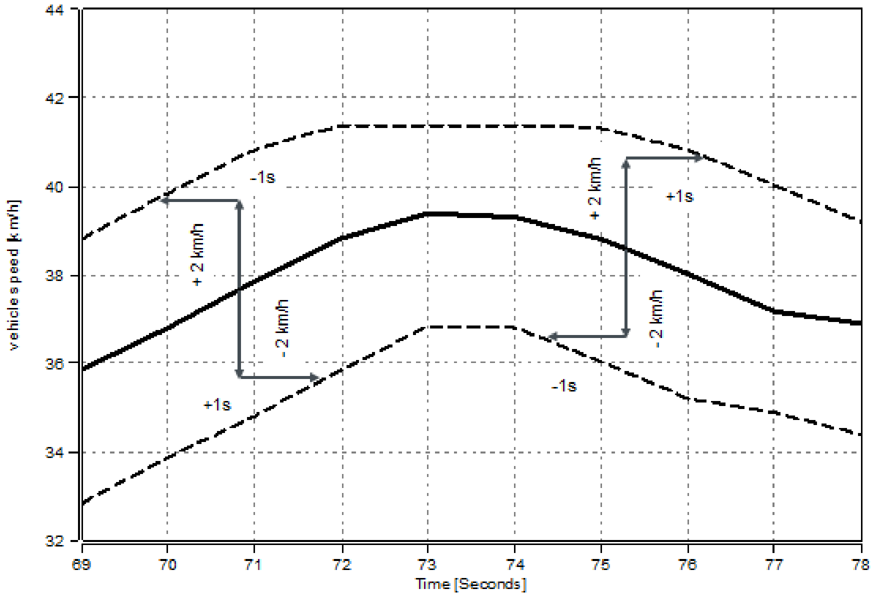
Figure A6/2

Speed trace tolerances



1.2.6.7. Accelerations

The vehicle shall be operated with the appropriate accelerator control movement necessary to accurately follow the speed trace.

The vehicle shall be operated smoothly, following representative shift speeds and procedures.

For manual transmissions, the accelerator controller shall be released during each shift and the shift shall be accomplished in minimum time.

If the vehicle cannot follow the speed trace, it shall be operated at maximum available power until the vehicle speed reaches the speed prescribed for that time in the driving schedule.

1.2.6.8. Decelerations

1.2.6.8.1. During decelerations of the cycle, the driver shall deactivate the accelerator control but shall not manually disengage the clutch until the point described in paragraph 4(c) of Sub-Annex 2.

1.2.6.8.1.1. If the vehicle decelerates faster than prescribed by the speed trace, the accelerator control shall be operated such that the vehicle accurately follows the speed trace.

1.2.6.8.1.2. If the vehicle decelerates too slowly to follow the intended deceleration, the brakes shall be applied such, that it is possible to accurately follow the speed trace.

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1.2.6.9. Unexpected engine stop

1.2.6.9.1. If the engine stops unexpectedly, the preconditioning or Type 1 test shall be declared void.

1.2.6.10. After completion of the cycle, the engine shall be switched off.

1.2.7. Soaking

1.2.7.1. After preconditioning, and before testing, vehicles shall be kept in an area with ambient conditions as described in paragraph 1.2.2.2.2. of this Sub-Annex.

1.2.7.2. The vehicle shall be soaked for a minimum of 6 hours and a maximum of 36 hours with the bonnet opened or closed until the engine oil temperature and coolant temperature, if any, are within ± 2 K of the set point. If not excluded by specific provisions for a particular vehicle, cooling may be accomplished by forced cooling down to within ± 2 K of the set point temperature. If cooling is accelerated by fans, the fans shall be placed so that the maximum cooling of the drive train, engine and exhaust after-treatment system is achieved in a homogeneous manner.

1.2.8. Emissions test (Type 1 test)

1.2.8.1. The test cell temperature at the start of the test shall be 296 K ± 3 K measured at a frequency of minimum 1 Hz.

1.2.8.2. The test vehicle shall be pushed onto a dynamometer.

1.2.8.2.1. The drive wheels of the vehicle shall be placed on the dynamometer without starting the engine.

1.2.8.2.2. The drive-wheel tyre pressures shall be set in accordance with the provisions of paragraph 1.2.4.5. above.

1.2.8.2.3. The bonnet shall be closed.

1.2.8.2.4. An exhaust connecting tube shall be attached to the vehicle tailpipe(s) immediately before starting the engine.

1.2.8.3. Engine starting and driving

1.2.8.3.1. The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions.

1.2.8.3.2. The vehicle shall be driven as described in paragraphs 1.2.6.4. to 1.2.6.10. of this Sub-Annex over the applicable WLTC, as described in Sub-Annex 1.

1.2.8.6. RCB data shall be recorded for each phase of the WLTC as defined in Appendix 2 to this Sub-Annex.

1.2.9. Gaseous sampling

Gaseous samples shall be collected in bags and the compounds analysed at the end of the test or a test phase, or the compounds may be analysed continuously and integrated over the cycle.

1.2.9.1. The following steps shall be taken prior to each test.

1.2.9.1.1. The purged, evacuated sample bags shall be connected to the dilute exhaust and dilution air sample collection systems.

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Comment [RCG128]: Updated in 230414 GTR benchmark – to simplify the cross-referencing

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Comment [RCG129]: Updated in 230414 GTR benchmark

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1.2.9.1.2. Measuring instruments shall be started according to the instrument manufacturers' instructions.

1.2.9.1.3. The CVS heat exchanger (if installed) shall be pre-heated or pre-cooled to within its operating test temperature tolerance as specified in paragraph 3.3.5.1. of Sub-Annex 5.

1.2.9.1.4. Components such as sample lines, filters, chillers and pumps shall be heated or cooled as required until stabilised operating temperatures are reached.

1.2.9.1.5. CVS flow rates shall be set according to paragraph 3.3.4. of Sub-Annex 5, and sample flow rates shall be set to the appropriate levels.

1.2.9.1.6. Any electronic integrating device shall be zeroed and may be re-zeroed before the start of any cycle phase.

1.2.9.1.7. For all continuous gas analysers, the appropriate ranges shall be selected. These may be switched during a test only if switching is performed by changing the calibration over which the digital resolution of the instrument is applied. The gains of an analyser's analogue operational amplifiers may not be switched during a test.

1.2.9.1.8. All continuous gas analysers shall be zeroed and calibrated using gases fulfilling the requirements of paragraph 6. of Sub-Annex 5.

1.2.10. Particulate mass sampling

1.2.10.1. The following steps shall be taken prior to each test.

1.2.10.1.1. Filter selection

1.2.10.1.1.1. A single particulate filter without back-up shall be employed for the complete applicable WLTC. In order to accommodate regional cycle variations, a single filter may be employed for the first three phases and a separate filter for the fourth phase.

1.2.10.1.2. Filter preparation

At least 1 hour before the test, the filter shall be placed in a petri dish protecting against dust contamination and allowing air exchange, and placed in a weighing chamber for stabilization.

At the end of the stabilization period, the filter shall be weighed and its weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within 8 hours of its removal from the weighing chamber.

The filter shall be returned to the stabilization room within 1 hour after the test and shall be conditioned for at least 1 hour before weighing.

1.2.10.1.2.2. The particulate sample filter shall be carefully installed into the filter holder. The filter shall be handled only with forceps or tongs. Rough or abrasive filter handling will result in erroneous weight determination. The filter holder assembly shall be placed in a sample line through which there is no flow.

1.2.10.1.2.3. It is recommended that the microbalance be checked at the start of each weighing session within 24 hours of the sample weighing by weighing one reference weight of approximately 100 mg. This weight shall be weighed three times and the average result recorded. If the average result of the weighings is ± 5 µg of the result from the previous weighing session then the weighing session and balance are considered valid.

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Comment [RCG131]: NB: this para is repeated in 1.2.12.5.2.1.

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1.2.11. Particle number sampling

1.2.11.1. The following steps shall be taken prior to each test:

1.2.11.1.1. The particle specific dilution system and measurement equipment shall be started and made ready for sampling;

1.2.11.1.2. The correct function of the particle counter and volatile particle remover elements of the particle sampling system shall be confirmed according to the procedures listed in paragraphs 1.2.11.1.2.1. to 1.2.11.1.2.4.

1.2.11.1.2.1. A leak check, using a filter of appropriate performance attached to the inlet of the entire particle number measurement system (VPR and PNC), shall report a measured concentration of less than 0.5 particles cm^{-3}.

1.2.11.1.2.2. Each day, a zero check on the particle counter, using a filter of appropriate performance at the counter inlet, shall report a concentration of ≤ 0.2 particles cm^{-3}. Upon removal of the filter, the particle counter shall show an increase in measured concentration to at least 100 particles cm^{-3} when sampling ambient air and a return to ≤ 0.2 particles cm^{-3} on replacement of the filter.

1.2.11.1.2.3. It shall be confirmed that the measurement system indicates that the evaporation tube, where featured in the system, has reached its correct operating temperature.

1.2.11.1.2.4. It shall be confirmed that the measurement system indicates that the diluter PND_1 has reached its correct operating temperature.

1.2.12. Sampling during the test

1.2.12.1. The dilution system, sample pumps and data collection system shall be started.

1.2.12.2. The particulate mass and particle number sampling systems shall be started.

1.2.12.3. Particle number shall be measured continuously. The average concentrations shall be determined by integrating the analyser signals over each phase.

1.2.12.4. Sampling shall begin before or at the initiation of the engine start up procedure and end on conclusion of the cycle.

1.2.12.5. Sample switching

1.2.12.5.1. Gaseous emissions

1.2.12.5.1.1. Sampling from the diluted exhaust and dilution air shall be switched from one pair of sample bags to subsequent bag pairs, if necessary, at the end of each phase of the applicable WLTC to be driven.

1.2.12.5.2. Particulate matter

1.2.12.5.2.1. A single particulate filter without back-up shall be employed for the complete applicable WLTC. In order to accommodate regional cycle variations, a single filter may be employed for the first three phases and a separate filter for the fourth phase.

1.2.12.6. Dynamometer distance shall be recorded for each phase.

1.2.13. Ending the test

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1.2.13.1. The engine shall be turned off immediately after the end of the last part of the test.

1.2.13.2. The constant volume sampler (CVS) or other suction device shall be turned off, or the exhaust tube from the tailpipe or tailpipes of the vehicle shall be disconnected.

1.2.13.3. The vehicle may be removed from the dynamometer.

1.2.14. Post-test procedures

1.2.14.1. Gas analyser check

1.2.14.1.1. Zero and calibration gas reading of the analysers used for continuous diluted 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 per cent of the calibration gas value.

1.2.14.2. Bag analysis

1.2.14.2.1. Exhaust gases and dilution air contained in the bags shall be analysed as soon as possible and exhaust gases in any event not later than 30 minutes after the end of the cycle phase.

The gas reactivity time for compounds in the bag shall be taken into consideration.

1.2.14.2.2. As soon as practical prior to analysis, the analyser range to be used for each compound shall be set to zero with the appropriate zero gas.

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

1.2.14.2.4. The analysers zero settings shall then be rechecked: if any reading differs by more than 2 per cent of the range from that set in paragraph 1.2.14.2.2. above, the procedure shall be repeated for that analyser.

1.2.14.2.5. The samples shall then be analysed.

1.2.14.2.6. After the analysis, zero and calibration points shall be rechecked using the same gases. The test shall be considered acceptable if the difference is less than 2 per cent of the calibration gas value. .

1.2.14.2.7. The flow rates and pressures of the various gases through analysers shall be the same as those used during calibration of the analysers.

1.2.14.2.8. The content of each of the compounds measured shall be recorded after stabilization of the measuring device.

1.2.14.2.9. The mass and number of all emissions, where applicable, shall be calculated according to Sub-Annex 7.

1.2.14.3. Particulate filter weighing

1.2.14.3.1. The particulate filter shall be returned to the weighing chamber no later than 1 hour after completion of the test. It shall be conditioned in a petri dish, which is protected against dust contamination and allows air exchange, for at least 1 hour, and then weighed. The gross weight of the filter shall be recorded.

1.2.14.3.2. 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.

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1.2.14.3.3. If the specific weight of any reference filter changes by more than ± 5µg between sample filter weighings, then the sample filter and reference filters shall be reconditioned in the weighing room and then reweighed.

1.2.14.3.4. The comparison of reference filter weighings 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 after the reference filters were placed in the weighing room. The averaging period shall be at least one day but not more than 15 days.

1.2.14.3.5. Multiple reconditionings and reweighings of the sample and reference filters are permissible until a period of 80 hours has elapsed following the measurement of gases from the emissions test. If, prior to or at the 80 hour point, more than half the number of reference filters meet the ±5 µg criterion, then the sample filter weighing can be considered valid. If, at the 80 hour point, two reference filters are employed and one filter fails the ±5 µg 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.

1.2.14.3.6. In the case that 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 one day.

1.2.14.3.7. If the weighing room stability criteria outlined in paragraph 4.2.2.1. of Sub-Annex 5 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.

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Sub-Annex 6 -Appendix 1

Emissions test procedure for all vehicles equipped with periodically regenerating systems

1. General

1.1. This Appendix defines the specific provisions regarding testing a vehicle equipped with periodically regenerating systems as defined in paragraph 3.8.1. of this Annex.

1.2. During cycles where regeneration occurs, emission standards can be exceeded. If a periodic regeneration occurs at least once per Type 1 test and 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. This Appendix does not apply to continuously regenerating systems.

1.3. At the request of the manufacturer, and subject to the agreement of the approval authority, the test procedure specific to periodically regenerating systems will not apply to a regenerative device if the manufacturer provides data demonstrating that, during cycles where regeneration occurs, emissions remain below the emissions limits applied for the relevant vehicle category.

1.4. The Extra High$_2$ phase shall be excluded for determining the regenerative factor (K$_i$) for Class 2 vehicles.

1.5. The Extra High$_3$ phase shall be excluded for determining the regenerative factor (K$_i$) for Class 3 vehicles.

2. Test Procedure

The test vehicle shall be capable of inhibiting or permitting the regeneration process provided that this operation has no effect on original engine calibrations. Prevention of regeneration shall only be permitted during loading of the regeneration system and during the preconditioning cycles. It shall not be permitted during the measurement of emissions during the regeneration phase. The emission test shall be carried out with the unchanged original equipment manufacturer's (OEM) control unit.

2.1. Exhaust emission measurement between two WLTCs with regeneration events.

2.1.1. Average emissions between regeneration events and during loading of the regenerative device shall be determined from the arithmetic mean of several approximately equidistant (if more than 2) Type 1 tests. As an alternative, the manufacturer may provide data to show that the emissions remain constant (± 15 per cent) on WLTCs between regeneration events. In this case, the emissions measured during the Type 1 test may be used. In any other case, emissions measurement for at least two Type 1cycles must be completed: one immediately after regeneration (before new loading) and one as close as possible prior to a regeneration phase. All emissions measurements shall be carried out according to this Sub-Annex and all calculations shall be carried out according to paragraph 3. of this Appendix.

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Comment [RCG137]: AdminWG 040414 – delete “by the Contracting Party” and replace “may” with “shall”.

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2.1.2. The loading process and K_i determination shall be made during the Type 1 driving 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.

2.1.3. The number of cycles (D) between two WLTCs where regeneration events occur, the number of cycles over which emission measurements are made (n), and mass emissions measurement (M'_{sij}) for each compound (i) over each cycle (j) shall be included in the test report.

2.2. Measurement of emissions during regeneration events

2.2.1. Preparation of the vehicle, if required, for the emissions test during a regeneration phase, may be completed using the preconditioning cycles in paragraph 1.2.6. of this Sub-Annex or equivalent engine test bench cycles, depending on the loading procedure chosen in paragraph 2.1.2. above.

2.2.2. The test and vehicle conditions for the Type 1 test described in this Annex apply before the first valid emission test is carried out.

2.2.3. Regeneration shall not occur during the preparation of the vehicle. This may be ensured by one of the following methods:

2.2.3.1. A "dummy" regenerating system or partial system may be fitted for the preconditioning cycles;

2.2.3.2. Any other method agreed between the manufacturer and the approval authority.

2.2.4. A cold start exhaust emission test including a regeneration process shall be performed according to the applicable WLTC.

2.2.5. If the regeneration process requires more than one WLTC, each WLTC shall be completed. Use of a single particulate matter filter for multiple cycles required to complete regeneration is permissible.

2.2.5.1. If more than one WLTC is required, subsequent Type 1 cycle(s) shall be driven immediately, without switching the engine off, until complete regeneration has been achieved. In the case where the number of gaseous emission bags required for the multiple cycles would exceed the number of bags available, the time necessary to set up a new test should be as short as possible. The engine must be switched off during this period.

2.2.6. The emission values during regeneration (M_{ri}) for each compound (i) shall be calculated according to paragraph 3. below. The number of operating cycles (d) measured for complete regeneration shall be included in the test report.

3. Calculations

3.1. Calculation of the exhaust and CO_2 emissions, and fuel consumption of a single regenerative system

$$M_{si} = \frac{\sum_{j=1}^{n} M'_{sij}}{n} \quad \text{for } n \geq 1 \qquad (1)$$

$$M_{ri} = \frac{\sum_{j=1}^{d} M'_{rij}}{d} \quad \text{for } d \geq 1 \qquad (2)$$

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$$M_{pi} = \frac{M_{si} \times D + M_{ri} \times d}{D + d} \qquad (3)$$

where for each compound (i) considered:

M'_{sij} are the mass emissions of compound (i) over test cycle (j) without regeneration, g/km;

M'_{rij} are the mass emissions of compound (i) over test cycle (j) during regeneration, g/km (if $d > 1$, the first WLTC test shall be run cold and subsequent cycles hot);

M_{si} are the mean mass emissions of compound (i) without regeneration, g/km;

M_{ri} are the mean mass emissions of compound (i) during regeneration, g/km;

M_{pi} are the mean mass emissions of compound (i), g/km;

n is the number of test cycles, between cycles where regenerative events occur, during which emissions measurements on Type 1 WLTCs are made, ≥ 1;

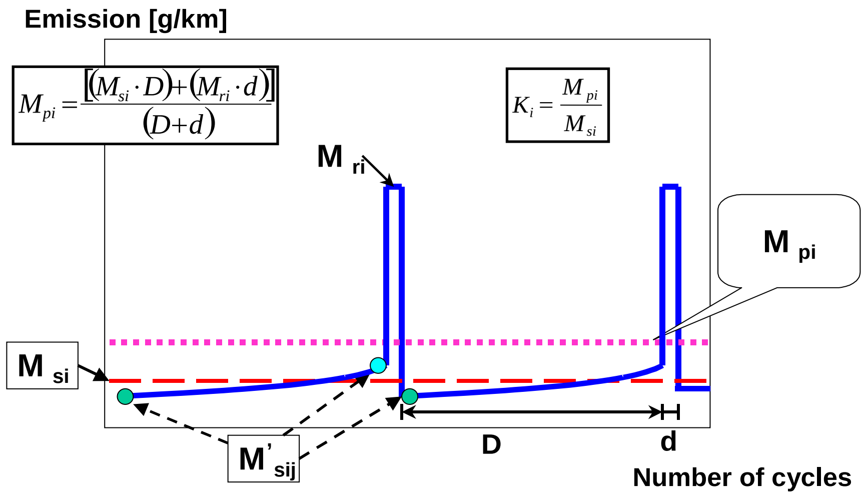
d is the number of complete operating cycles required for regeneration;

D is the number of complete operating cycles between two cycles where regeneration events occur.

The calculation of M_{pi} is shown graphically in Figure A6. App1/1.

Figure A6.App1/1

Parameters measured during emissions test during and between cycles where regeneration occurs (schematic example, the emissions during D may increase or decrease)



3.1.1. Calculation of the regeneration factor K_i for each compound (i) considered.

The manufacturer may elect to determine for each compound independently either additive offsets or multiplicative factors.

K_i factor: $K_i = \frac{M_{pi}}{M_{si}}$ (4)

K_i offset: $K_i = M_{pi} - M_{si}$ (5)

K_i results, and the manufacturer's choice of type of factor shall be included in the test report.

K_i may be determined following the completion of a single regeneration sequence comprising measurements before, during and after regeneration events as shown in Figure A6.App1/1.

3.2. Calculation of exhaust and CO_2 emissions, and fuel consumption of multiple periodic regenerating systems

The following shall be calculated for (a) one Type 1 operation cycle for exhaust emissions and (b) for each individual phase for CO_2 emissions and fuel consumption.

$$M_{sik} = \frac{\sum_{j=1}^{n_k} M'_{sik,j}}{n_k} \text{ for } n_j \geq 1 \quad (6)$$

$$M_{rik} = \frac{\sum_{j=1}^{d_k} M'_{rik,j}}{d_k} \text{ for } d \geq 1 \quad (7)$$

$$M_{si} = \frac{\sum_{k=1}^{x} M_{sik} \times D_k}{\sum_{k=1}^{x} D_k} \quad (8)$$

$$M_{ri} = \frac{\sum_{k=1}^{x} M_{rik} \times d_k}{\sum_{k=1}^{x} d_k} \quad (9)$$

$$M_{pi} = \frac{M_{si} \times \sum_{k=1}^{x} D_k + M_{ri} \times \sum_{k=1}^{x} d_k}{\sum_{k=1}^{x} (D_k + d_k)} \quad (10)$$

$$M_{pi} = \frac{\sum_{k=1}^{x} (M_{sik} \times D_k + M_{rik} \times d_k)}{\sum_{k=1}^{x} (D_k + d_k)} \quad (11)$$

K_i factor: $K_i = \frac{M_{pi}}{M_{si}}$ (12)

K_i offset: $K_i = M_{pi} - M_{si}$ (13)

where:

M_{si} are the mean mass emissions of all events k of compound (i) without regeneration, g/km;

M_{ri} are the mean mass emissions of all events k of compound (i) during regeneration, g/km;

M_{pi} are the mean mass emission of all events k of compound (i), g/km;

M_{sik} are the mean mass emissions of event k of compound (i) without regeneration, g/km;

M_{rik} are the mean mass emissions of event k of compound (i) during regeneration, g/km;

$M'_{sik,j}$ are the mass emissions of event k of compound (i) in g/km without regeneration measured at point j where $1 \leq j \leq n_k$, g/km;

Comment [RCG139]: AdminWG 290414 – confirmed that Msi and Mpi should be deleted.

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11.05.2014: H. Schmidt believes that the text should remain as is, i.e., Msi, Mpi and Ki must be recorded.

For AdminWG 150514
Should we therefore reinstate Msi and Mpi and say that they should be recorded?

AdminWG 150514 – further discussions required on test report and information for the appendix. Reporting of coastdown mode and dynamometer mode.

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$M'_{rik,j}$	are the mass emissions of event k of compound (i) during regeneration (when j > 1, the first Type 1 test is run cold, and subsequent cycles are hot) measured at operating cycle j where $1 \le j \le d_k$, g/km;
n_k	are the number of complete test cycles of event k, between two cycles where regenerative phases occur, during which emissions measurements (Type 1 WLTCs or equivalent engine test bench cycles) are made, ≥ 2;
d_k	is the number of complete operating cycles of event k required for complete regeneration;
D_k	is the number of complete operating cycles of event k between two cycles where regenerative phases occur;
x	is the number of complete regeneration events.

The calculation of M_{pi} is shown graphically in Figure A6 App1/2.

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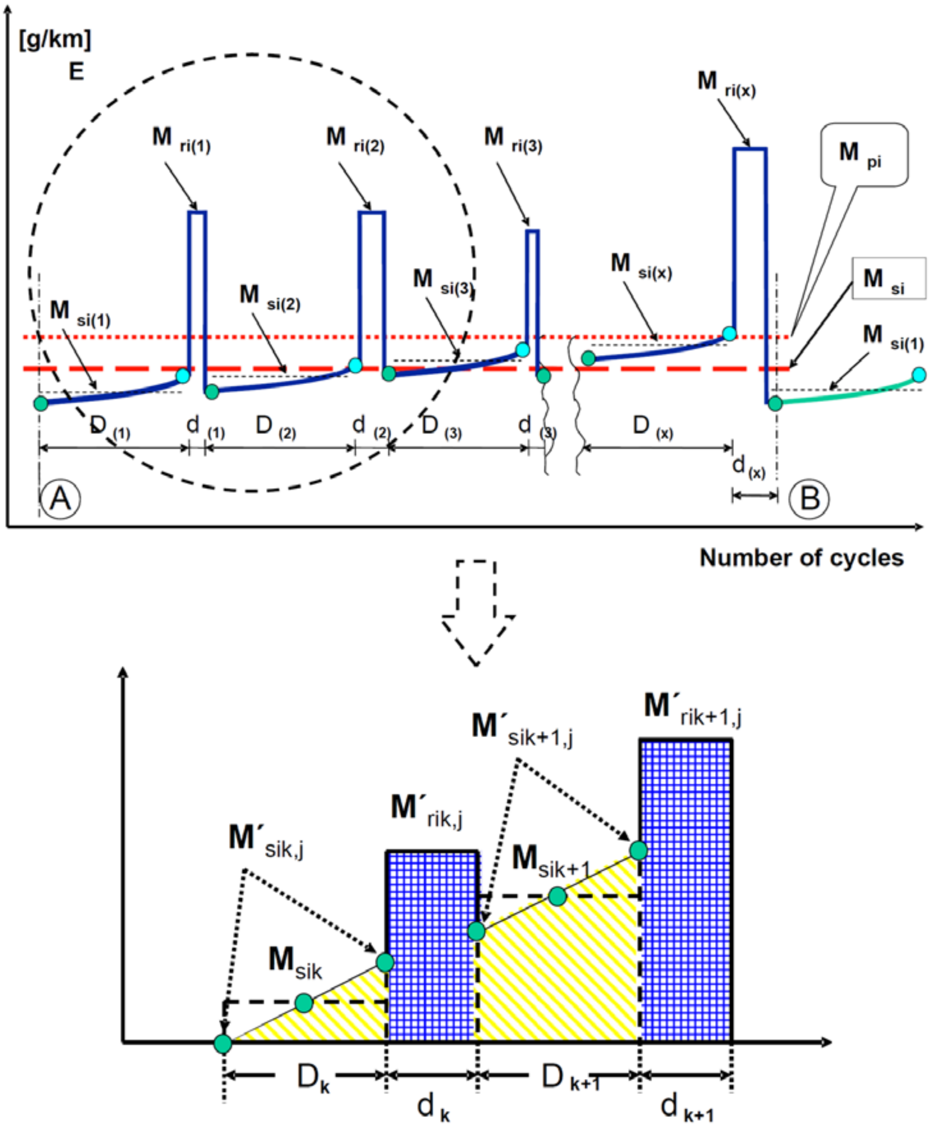
Figure A6.App1/2

Parameters measured during emissions test during and between cycles where regeneration occurs (schematic example)



The calculation of K_i for multiple periodic regenerating systems is only possible after a certain number of regeneration events for each system.

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After performing the complete procedure (A to B, see Figure A6 App1/2), the original starting condition A should be reached again.

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Sub-Annex 6 -Appendix 2

Test procedure for electric power supply system monitoring

1. General

This Appendix defines the specific provisions regarding the correction of test results for fuel consumption (l/100 km) and CO_2 emissions (g/km) as a function of the energy balance ΔE_{REESS} for the vehicle batteries.

The corrected values for fuel consumption and CO_2 emissions should correspond to a zero energy balance ($\Delta E_{REESS} = 0$), and are calculated using a correction coefficient determined as defined below.

2. Measurement equipment and instrumentation

2.1. Current transducer

2.1.1. The battery current shall be measured during the tests using a clamp-on or closed type current transducer. The current transducer (i.e. a 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 full scale deflection, whichever is smaller.

2.1.2. The current transducer shall be fitted on one of the cables connected directly 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 this is not feasible, the manufacturer shall support the approval authority by providing the means to connect a current transducer to the battery cables in the above described manner.

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2.1.3. Current transducer output shall be sampled with a minimum frequency of 5 Hz. The measured current shall be integrated over time, yielding the measured value of Q, expressed in ampere-hours (Ah).

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2.2. Vehicle on-board data

2.2.1. Alternatively, the battery current shall be determined using vehicle-based data. In order to use this measurement method, the following information shall be accessible from the test vehicle:

(a) Integrated charging balance value since last ignition run in Ah;

(b) Integrated on-board data charging balance value calculated with a minimum sample frequency of 5 Hz;

(c) The charging balance value via an OBD connector as described in SAE J1962.

2.2.2. The accuracy of the vehicle on-board battery charging and discharging data shall be demonstrated by the manufacturer to the approval authority.

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The manufacturer may create a battery monitoring vehicle family to prove that the vehicle on-board battery charging and discharging data are correct. The accuracy of the data shall be demonstrated on a representative vehicle.

The following family criteria shall be valid:

(a) Identical combustion processes;

(b) Identical charge and/or recuperation strategy (software battery data module);

(c) On-board data availability;

(d) Identical charging balance measured by battery data module;

(e) Identical on-board charging balance simulation.

3. Measurement procedure

3.1. External battery charging

Before the preconditioning test cycle, the battery shall be fully charged. The battery shall not be charged again before the official testing according to paragraph 1.2.6.2. of this Sub-Annex.

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3.2. 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.

3.3. The electricity balance, Q, measured in the electric power supply system, is used as a measure of the difference in the REESS energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined for the total WLTC for the applicable vehicle class.

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3.4. Separate values of Q_{phase} shall be logged over the cycle phases required to be driven for the applicable vehicle class.

3.5. $CO_{2,CS}$ and FC_{CS} test results shall be corrected as a function of the REESS energy balance RCB.

3.6. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:

(a) The manufacturer can prove that there is no relation between the energy balance and fuel consumption;

(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging;

(c) ΔE_{REESS} as calculated from the test result corresponds to REESS charging and discharging. ΔE_{REESS}, expressed as a percentage of the energy content of the fuel consumed over the cycle, is calculated in the equation below:

$$\Delta E_{REESS} = \frac{0.0036 \times RCB \times U_{REESS}}{E_{Fuel}} \times 100 \quad (1)$$

where:

ΔE_{REESS} is the change in the REESS energy content, per cent;

U_{REESS} is the nominal REESS voltage, V;

RCB is REESS charging balance over the whole cycle, Ah;

E_{Fuel} is the energy content of the consumed fuel, MJ.

ΔE_{REESS} is lower than the RCB correction criteria, according to the equation below and Table A6.App2/1 below;

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$$\Delta E_{REESS} \leq \text{RCB correction criterion} \quad (2)$$

Table A6.App2/1
RCB correction criteria

Cycle	*WLTC city(low + medium)*	*WLTC (low + medium + high)*	*WLTC(low + medium + high + extra high)*
RCB correction criterion (%)	1.5	1	0.5

4. Correction Method

4.1. To apply the correction function, the electric power to the battery must be calculated from the measured current and the nominal voltage value for each phase of the WLTC test:

$$\Delta E_{el-phase(i)} = U_{REESS} \times \int_0^{t-end} I(t)_{phase(i)} dt \quad (3)$$

where:

$\Delta E_{el-phase(i)}$ is the change in the electrical REESS energy content of phase i, MJ;

U_{REESS} is the nominal REESS voltage, V;

$I(t)_{phase(i)}$ is the electric current in phase (i), A;

$t - end$ is the time at the end of phase (i), seconds (s).

4.2. For correction of fuel consumption, l/100 km, and CO_2 emissions, g/km, combustion process-dependent Willans factors from Table A6.App2/2 (paragraph 4.8. below) shall be used.

4.3. The resulting fuel consumption difference of the engine for each WLTC phase due to load behaviour of the alternator for charging a battery shall be calculated as shown below:

$$\Delta FC_{phase(i)} = \Delta E_{el-phase(i)} \times \frac{1}{\eta_{alternator}} \times Willans_{factor} \quad (4)$$

where:

$\Delta FC_{phase(i)}$ is the resulting fuel consumption difference of phase (i), l;

$\Delta E_{el-phase(i)}$ is the change in the electrical REESS energy content of phase (i), MJ;

$\eta_{alternator}$ is the efficiency of the alternator;

$Willans_{factor}$ is the combustion process specific Willans factor as defined in Table A6.App2/2.

4.4. The resulting CO_2 emissions difference of the engine for each WLTC phase due to load behaviour of the alternator for charging a battery shall be calculated as shown below:

$$\Delta CO_{2,phase(i)} = \Delta E_{el-phase(i)} \times \frac{1}{\eta_{alternator}} \times Willans_{factor} \quad (5)$$

where:

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$\Delta CO_{2,phase(i)}$ is the resulting CO_2-emission difference of phase (i), g;

$\Delta E_{el-phase(i)}$ is the change in the electrical REESS energy content of phase (i), MJ;

$\eta_{alternator}$ is the efficiency of the alternator;

$Willans_{factor}$ is the combustion process specific Willans factor as defined in Table A6.App2/2.

4.5. For this specific calculation, a fixed electric power supply system alternator efficiency shall be used:

$\eta_{alternator} = 0.67$ for electric power supply system battery alternators

4.6. The consumption difference of the engine for the WLTC test is the sum over the (i) single phases as shown below:

$$\Delta FC_{cycle} = \sum_{i=1}^{n} \Delta FC_{phase\,(i)} \quad (6)$$

where:

ΔFC_{cycle} is the change in consumption over the whole cycle, l.

4.7. The CO_2 emissions difference of the engine for the WLTC test is the sum over the (i) single phases as shown below:

$$\Delta CO_{2,cycle} = \sum_{i=1}^{n} \Delta CO_{2,phase\,(i)} \quad (7)$$

where:

$\Delta CO_{2,cycle}$ is the change in CO_2-emission over the whole cycle, g.

4.8. For correction of the fuel consumption, l/100 km, and CO_2 emission, g/km, the Willans factors in Table A6.App2/2 shall be used.

Table A6.App2/2

Willans factors

			Naturally aspirated	*Pressure charged*
Positive ignition	Petrol (E0)	l/kWh	0.264	0.28
		gCO_2/kWh	630	668
	Petrol (E5)	l/kWh	0.268	0.284
		gCO_2/kWh	628	666
	CNG (G20)	m³/kWh	0.259	0.275
		gCO_2/kWh	465	493
	LPG	l/kWh	0.342	0.363
		gCO_2/kWh	557	591
	E85	l/kWh	0.367	0.389
		gCO_2/kWh	608	645
Compression ignition	Diesel (B0)	l/kWh	0.22	0.22
		gCO_2/kWh	581	581
	Diesel (B5)	l/kWh	0.22	0.22
		gCO_2/kWh	581	581

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Comment [RCG142]: Update table for UNECE fuels NG/Biomethane?

Comment [RCG143]: AdminWG 040414 – need to contact experts for information on this table and to obtain factors for fuels to be added.

E-mail query sent to Annette Feucht and Christoph Lueginger. They are looking into the issue.

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Comment [RCG144]: Add new rows for Petrol (E10)?

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Comment [RCG145]: Keep or delete?

Comment [RCG146]: Add rows for Diesel (B7)?

Sub-Annex 7

Calculations

1. General requirements

1.1. Calculations related specifically to hybrid and pure electric vehicles are described in Sub-Annex 8.

1.2. The calculations described in this Sub-Annex shall be used for vehicles using combustion engines.

1.3. The final test results shall be rounded in one step to the number of places to the right of the decimal point indicated by the applicable emission standard plus one additional significant figure. Intermediate steps in the calculations shall not be rounded.

1.4. The NO_x correction factor, KH, shall be rounded to two decimal places.

1.5. The dilution factor, DF, shall be rounded to two decimal places.

1.6. For information not related to standards, good engineering judgement shall be used.

2. Determination of diluted exhaust gas volume

2.1. Diluted exhaust gas volume calculation for a variable dilution device capable of operating at a constant or variable flow rate.

2.1.1. The parameters showing the volumetric flow shall be recorded continuously. The total volume shall be recorded for the duration of the test.

2.2. Volume calculation for a variable dilution device using a positive displacement pump

2.2.1. The volume shall be calculated using the following equation:

$$V = V_0 \times N \quad (1)$$

where:

V is the volume of the diluted gas, in litres per test (prior to correction);

V_0 is the volume of gas delivered by the positive displacement pump in testing conditions, N^{-1};

N is the number of revolutions per test.

2.2.1.1. Correcting the volume to standard conditions

2.2.1.1.1. The diluted exhaust gas volume, V, shall be corrected to standard conditions according to the following equation:

$$V_{mix} = V \times K_1 \times \left(\frac{P_B - P_1}{T_p}\right) \quad (2)$$

where:

$$K_1 = \frac{273.15\ (K)}{101.325\ (kPa)} = 2.6961 \quad (3)$$

P_B is the test room barometric pressure, kPa;

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P_1 is the vacuum at the inlet to the positive displacement pump relative to the ambient barometric pressure, kPa;

T_p is the average temperature of the diluted exhaust gas entering the positive displacement pump during the test, Kelvin (K).

3. Mass emissions

3.1. General requirements

3.1.1. Assuming no compressibility effects, all gases involved in the engine intake/combustion/exhaust process can be considered to be ideal according to Avogadro's hypothesis.

3.1.2. The mass M of gaseous compounds emitted by the vehicle during the test shall be determined by obtaining the product of the volumetric concentration of the gas in question and the volume of the diluted exhaust gas with due regard for the following densities under the reference conditions of 273.15 K and 101.325 kPa:

Carbon monoxide (CO)	ρ = 1.25 g/l
Carbon dioxide (CO_2)	ρ = 1.964 g/l
Hydrocarbons:	
for petrol (E0) ($C_1H_{1.85}$)	ρ = 0.619 g/l
for petrol (E5) ($C_1H_{1.89}O_{0.016}$)	ρ = 0.631 g/l
for petrol (E10) ($C_1H_{1.93}O_{0.033}$)	ρ = 0.645 g/1
for diesel (B0) ($C_1H_{1.86}$)	ρ = 0.619 g/1
for diesel (B5) ($C_1H_{1.86}O_{0.005}$)	ρ = 0.622 g/1
for diesel (B7) ($C_1H_{1.86}O_{0.007}$)	ρ = 0.623 g/1
for LPG ($C_1H_{2.525}$)	ρ = 0.649 g/l
for NG/biomethane (CH_4)	ρ = 0.714 g/l
for ethanol (E85) ($C_1H_{2.74}O_{0.385}$)	ρ = 0.932 g/l
Nitrogen oxides (NO_x)	ρ = 2.05 g/1
Nitrogen dioxide (NO_2)	ρ = 2.05 g/1
Nitrous oxide (N_2O)	ρ = 1.964 g/1

The density for NMHC mass calculations shall be equal to that of total hydrocarbons at 273.15 K and 101.325 kPa and is fuel-dependent.

3.2. Mass emissions calculation

3.2.1. Mass emissions of gaseous compounds shall be calculated using the following equation:

$$M_i = \frac{V_{mix} \times \rho_i \times KH \times C_i \times 10^{-6}}{d} \quad (4)$$

where:

M_i is the mass emissions of compound (i), g/km;

V_{mix} is the volume of the diluted exhaust gas expressed in litres per test and corrected to standard conditions (273.15 K and 101.325 kPa);

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Comment [RCG147]: For AdminWG 150514

Three different units for density
Reg 83 uses "d" for density in the equivalent text. 692/2008 and Reg 101 use "D" in the fuel consumption calculations (the GTR uses the Greek letter rho **ρ** – see para 6 of this sub – annex

Agreed to use **ρ** in the EU-WLTP

Comment [RCG148]: Add Ethanol E75? AdminWG 200314 – E75 won't be included until Phase 2. It is a low temperature test fuel.

Comment [RCG149]: AdminWG 040414 – Align fuels with those in 692/2008 (but not H2NG)

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ρ_i is the density of compound (i) in grams per litre at standard temperature and pressure (273.15 K and 101.325 kPa);

KH is a humidity correction factor applicable only to the mass emissions of oxides of nitrogen (NO_2 and NO_x);

C_i is the concentration of compound (i) in the diluted exhaust gas expressed in ppm and corrected by the amount of the compound (i) contained in the dilution air;

d is the distance driven over the corresponding WLTC, km.

3.2.1.1. The concentration of a gaseous compound in the diluted exhaust gas shall be corrected by the amount of the gaseous compound in the dilution air as follows:

$$C_i = C_e - C_d \times \left(1 - \frac{1}{DF}\right) \qquad (5)$$

where:

C_i is the concentration of gaseous compound (i) in the diluted exhaust gas corrected by the amount of gaseous compound (i) contained in the dilution air, ppm;

C_e is the measured concentration of gaseous compound (i) in the diluted exhaust gas, ppm;

C_d is the concentration of gaseous compound (i) in the air used for dilution, ppm;

DF is the dilution factor.

3.2.1.1.1. The dilution factor, DF, is calculated as follows:

$$DF = \frac{13.4}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for petrol (E0, E5, E10 and B0)} \qquad (6)$$

$$DF = \frac{13.5}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for diesel (B5 and B7)} \qquad (7)$$

$$DF = \frac{11.9}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for LPG} \qquad (8)$$

$$DF = \frac{9.5}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for NG/biomethane} \qquad (9)$$

$$DF = \frac{12.5}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for ethanol (E85)} \qquad (10)$$

$$DF = \frac{35.03}{C_{H2O} - C_{H2O-DF} + C_{H2} \times 10^{-4}} \quad \text{for hydrogen} \qquad (11)$$

3.2.1.1.2. General equation for the dilution factor (DF) for each reference fuel with an average composition of $C_xH_yO_z$ is:

$$DF = \frac{X}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \qquad (12)$$

where:

$$X = 100 \times \frac{x}{x + \frac{y}{2} + 3.76\left(x + \frac{y}{4} - \frac{z}{2}\right)} \qquad (13)$$

C_{CO2} is the concentration of CO_2 in the diluted exhaust gas contained in the sampling bag, per cent volume;

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Comment [RCG150]: R83 has different structure that has the general equation first. It then has a table defining the terms – that includes the terms for the hydrogen equation. The way the GTR is set out does not make this possible so for the time being I have added to end of paragraph 3.2.1.1.2.

Comment [RCG151]: AdminWG 040414 – Align fuels with those in 692/2008 (but not H2NG)

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Comment [RCG152]: AdminWG 150514 – Agreed that hydrogen should be added.

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Moved up [1]: where:

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

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

For the dilution factor for hydrogen the following definitions apply:

C_{H2O} is the concentration of H_2O in the diluted exhaust gas contained in the sampling bag, expressed in per cent volume;

C_{H2O-DC} is the concentration of H_2O in the air used for dilution, expressed in per cent volume;

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

Comment [RCG153]: AdminWG 150514 – Agreed that hydrogen should be added.

3.2.1.1.3. Methane measurement

3.2.1.1.3.1. For methane measurement using a GC-FID, NMHC is calculated as follows:

$$C_{NMHC} = C_{THC} - (Rf_{CH4} \times C_{CH4}) \quad (14)$$

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where:

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

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

C_{CH4} is the concentration of CH_4 in the diluted exhaust gas, 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 paragraph 5.4.3.2. of Sub-Annex 5.

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3.2.1.1.3.2. For methane measurement using a NMC-FID, the calculation of NMHC depends on the calibration gas/method used for the zero/calibration adjustment.

The FID used for the THC measurement (without NMC) shall be calibrated with propane/air in the normal manner.

For the calibration of the FID in series with NMC, the following methods are permitted :

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

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

$$C_{CH4} = \frac{C_{HC(w/NMC)} - C_{HC(w/oNMC)} \times (1 - E_E)}{r_h \times (E_E - E_M)} \quad (15)$$

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$$C_{NMHC} = \frac{C_{HC(w/oNMC)} \times (1 - E_M) - C_{HC(w/NMC)}}{E_E - E_M} \quad (16)$$

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

$$C_{CH4} = \frac{C_{HC(w/NMC)} \times r_h \times (1 - E_M) - C_{HC(w/oNMC)} \times (1 - E_E)}{r_h \times (E_E - E_M)} \qquad (17)$$

$$C_{NMHC} = \frac{C_{HC(w/oNMC)} \times (1 - E_M) - C_{HC(w/NMC)} \times r_h \times (1 - E_M)}{E_E - E_M} \qquad (18)$$

where:

$C_{HC(w/NMC)}$ is the HC concentration with sample gas flowing through the NMC, ppm C;

$C_{HC(w/oNMC)}$ is the HC concentration with sample gas bypassing the NMC, ppm C;

r_h is the methane response factor as determined per paragraph 5.4.3.2. of Sub-Annex 5;

E_M is the methane efficiency as determined per paragraph 3.2.1.1.3.3.1. below;

E_E is the ethane efficiency as determined per paragraph 3.2.1.1.3.3.2. below.

If r_h < 1.05, it may be omitted in equations 15, 17 and 18.

3.2.1.1.3.3. Conversion efficiencies of the non-methane cutter (NMC)

The NMC is used for the removal of the non-methane hydrocarbons from the sample gas by oxidizing all hydrocarbons except methane. Ideally, the conversion for methane is 0 per cent, and for the other hydrocarbons represented by ethane is 100 per cent. For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emission.

3.2.1.1.3.3.1. Methane conversion efficiency

The methane/air calibration gas shall be flowed to the FID through the NMC and bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$E_M = 1 - \frac{C_{HC(w/NMC)}}{C_{HC(w/oNMC)}} \qquad (19)$$

where:

$C_{HC(w/NMC)}$ is the HC concentration with CH_4 flowing through the NMC, ppm C;

$C_{HC(w/oNMC)}$ is the HC concentration with CH_4 bypassing the NMC, ppm C.

3.2.1.1.3.3.2. Ethane conversion efficiency

The ethane/air calibration gas shall be flowed to the FID through the NMC and bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$E_E = 1 - \frac{C_{HC(w/NMC)}}{C_{HC(w/oNMC)}} \qquad (20)$$

where:

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$C_{HC(w/NMC)}$ is the HC concentration with C_2H_6 flowing through the NMC, ppm C;

$C_{HC(w/oNMC)}$ is the HC concentration with C_2H_6 bypassing the NMC in ppm C.

If the ethane conversion efficiency of the NMC is 0.98 or above, E_E shall be set to 1 for any subsequent calculation.

3.2.1.1.3.4. If the methane FID is calibrated through the cutter, then E_M is 0.

Equation 10 from above becomes:

$$C_{CH4} = C_{HC(w/NMC)} \quad (21)$$

Equation 11 from above becomes:

$$C_{NMHC} = C_{HC(w/oNMC)} - C_{HC(w/NMC)} \times r_h \quad (22)$$

The density used for NMHC mass calculations shall be equal to that of total hydrocarbons at 273.15 K and 101.325 kPa and is fuel-dependent.

3.2.1.1.4. Flow weighted average concentration calculation

The following calculation method shall only be applied for CVS systems that are not equipped with a heat exchanger or for CVS systems with a heat exchanger that do not comply with paragraph 3.3.5.1. of Sub-Annex 5.

When the CVS flow rate q_{VCVS} over the test varies more than ± 3 per cent of the average flow rate, a flow weighted average shall be used for all continuous diluted measurements including PN:

$$C_e = \frac{\sum_{i=1}^{n} q_{VCVS}(i) \times \Delta t \times C(i)}{V} \quad (23)$$

where:

C_e is the flow-weighted average concentration;

$q_{VCVS}(i)$ is the CVS flow rate at time $t = i \times \Delta t$, m³/min;

$C(i)$ is the concentration at time $t = i \times \Delta t$, ppm;

Δt sampling interval, seconds (s);

V total CVS volume, m³.

3.2.1.2. Calculation of the NO_x humidity correction factor

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

$$KH = \frac{1}{1 - 0.0329 \times (H - 10.71)} \quad (24)$$

where:

$$H = \frac{6.211 \times R_a \times P_d}{P_B - P_d \times R_a \times 10^{-2}} \quad (25)$$

and:

H is the specific humidity, grams of water vapour per kilogram of dry air;

R_a is the relative humidity of the ambient air, per cent;

P_d is the saturation vapour pressure at ambient temperature, kPa;

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Comment [RCG154]: Should be "specific humidity"

AdminWG 080514 – text updated.
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P_B is the atmospheric pressure in the room, kPa.

The KH factor shall be calculated for each phase of the test cycle.

The ambient temperature and relative humidity shall be defined as the average of the continuously measured values during each phase.

3.2.1.3. Determination of NO_2 concentration from NO and NO_x

NO_2 is determined by the difference between NO_x concentration from the bag corrected for dilution air concentration and NO concentration from continuous measurement corrected for dilution air concentration

3.2.1.3.1. NO concentrations

3.2.1.3.1.1. NO concentrations shall be calculated from the integrated NO analyser reading, corrected for varying flow if necessary.

3.2.1.3.1.2. The average NO concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{NO} dt}{t_2 - t_1} \quad (26)$$

where:

$\int_{t_1}^{t_2} C_{NO} dt$ is the integral of the recording of the continuous dilute NO analyser over the test (t_2-t_1);

C_e is the concentration of NO measured in the diluted exhaust, ppm;

3.2.1.3.1.3. Dilution air concentration of NO is determined from the dilution air bag. Correction is carried out according to paragraph 3.2.1.1. of this Sub-Annex.

3.2.1.3.2. NO_2 concentrations

3.2.1.3.2.1. Determination NO_2 concentration from direct diluted measurement

3.2.1.3.2.2. NO_2 concentrations shall be calculated from the integrated NO_2 analyser reading, corrected for varying flow if necessary.

3.2.1.3.2.3. The average NO_2 concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{NO_2} dt}{t_2 - t_1} \quad (27)$$

where:

$\int_{t_1}^{t_2} C_{NO_2} dt$ is the integral of the recording of the continuous dilute NO_2 analyser over the test (t_2-t_1);

C_e is the concentration of NO_2 measured in the diluted exhaust, ppm.

3.2.1.3.2.4. Dilution air concentration of NO_2 is determined from the dilution air bags. Correction is carried out according to paragraph 3.2.1.1. of this Sub-Annex.

3.2.2. Determination of the HC mass emissions from compression-ignition engines

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

Comment [RCG155]: Deleted "." before dt

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Comment [RCG156]: *EXPERT PROPOSAL: 12.05.2014: experts (Carli/Hill/Vavra/Cova) agree that "continuous dilute" is OK here and in 3.2.1.3.2.3.*

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Comment [RCG157]: Updated in 230414 GTR benchmark

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Comment [RCG158]: Updated in 230414 GTR benchmark

Comment [RCG159]: Comment from GTR 280414:

28.04.2014: S. Carli suggests "continuous dilute" to replace "modal"

AdminWG 080514 – Serge D to confirm update with Les Hill

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$$C_e = \frac{\int_{t_1}^{t_2} C_{HC} dt}{t_2 - t_1} \qquad (28)$$

where:

$\int_{t_1}^{t_2} C_{HC}\, dt$ is the integral of the recording of the heated FID over the test (t_1 to t_2);

C_e is the concentration of HC measured in the diluted exhaust in ppm of C_i and is substituted for C_{HC} in all relevant equations.

3.2.2.1.1. Dilution air concentration of HC shall be determined from the dilution air bags. Correction shall be carried out according to paragraph 3.2.1.1. of this Sub-Annex.

3.2.3. CO_2 calculation for individual vehicles in a CO_2 vehicle family

3.2.3.1. CO_2 emissions without using the interpolation method

If the road load and emissions have not been measured on test vehicle L in addition to test vehicle H, the value M_{CO_2}, as calculated in paragraph 3.2.1. above, shall be attributed to all individual vehicles in the CO_2 vehicle family and the CO_2 interpolation method is not applicable.

3.2.3.2. CO_2 emissions using the interpolation method

If the road load and emissions are measured on test vehicles L and H, the CO_2 emission for each individual vehicle in the CO_2 vehicle family may be calculated according to the CO_2 interpolation method outlined in paragraphs 3.2.3.2.1. to 3.2.3.2.2.6.

3.2.3.2.1. Determination of CO_2 emissions test vehicles L and H

The mass of CO_2 emissions, M_{CO_2}, for test vehicles L and H shall be determined according to the calculation in paragraph 3.2.1. above for the individual cycle phases p of the WLTC applicable for the class of the CO_2 vehicle family and are referred to as $M_{CO_2-L,p}$ and $M_{CO_2-H,p}$ respectively.

3.2.3.2.2. Road load calculation for an individual vehicle

3.2.3.2.2.1. Mass of the individual vehicle

The selected test masses TM_L and TM_H as determined in paragraph 4.2.1.3.1. of Sub-Annex 4 shall be used as input for the interpolation method.

The mass of the optional equipment m_o shall be calculated for the individual vehicle according to the following equation:

$$m_o = \sum_{i=1}^{n} \Delta m_i \qquad (29)$$

where:

m_o is the difference in mass between the individual vehicle and TM_L, kg

Δm_i is the mass of an individual option i on the vehicle (Δm_i is positive for an option that adds mass with respect to TM_L and vice versa), kg;

n is the number of options that are different between the individual vehicle and test vehicle L.

The value of m_o for test vehicle H shall be the same as the difference between TM_H and TM_L.

Comment [RCG160]: Updated in 230414 GTR benchmark

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Comment [RCG161]: Updated in 230414 GTR benchmark

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Comment [RCG162]: ACEA (W.Coleman) proposal

The ~~selected~~ test masses ~~TML and TMH as determined in paragraph 4.2.1.3.1. of Annex 4~~**of vehicles H and L** shall be used as input for the interpolation method.

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Comment [RCG163]: ACEA (W.Coleman) proposal
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Comment [RCG164]: ACEA (W.Coleman) proposal
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The mass of the individual vehicle is calculated according to the following equation:

$$TM_{ind} = TM_L + m_o \quad (30)$$

where TM_{ind} is the mass of the individual vehicle used as input for the CO_2 interpolation method.

If the same test mass was used for test vehicles L and H, the value of TM_{ind} shall be set to TM_H for the interpolation method.

3.2.3.2.2.2. Rolling resistance of the individual vehicle

According to paragraph 4.2.2.1. of Sub-Annex 4, the actual rolling resistance values for the selected tyres on test vehicle L, RR_L, and test vehicle H, RR_H, shall be used as input for the interpolation method.

For the tyres fitted to the individual vehicle, the value of the rolling resistance RR_{ind} shall be set to the class value of the applicable tyre rolling resistance class, according to Table A4/1of Sub-Annex 4.

If the same tyres were fitted to test vehicles L and H, the value of RR_{ind} for the interpolation method shall be set to RR_H

3.2.3.2.2.3. Aerodynamic drag of the individual vehicle

The aerodynamic drag shall be measured for each of the drag influencing options at a certified wind tunnel fulfilling the requirements of paragraph 3.2. of Sub-Annex 4.

The approval authority shall verify if the wind tunnel facility is qualified to accurately determine the $\Delta(C_d \times A_f)$ for options and/or body shapes that differ between test vehicle L and H. If the wind tunnel facility is not qualified, the $C_d \times A_f$ for vehicle H shall apply for the whole CO_2 vehicle family. The aerodynamic drag of options on the exterior of the individual vehicle shall be calculated according to the following equation:

$$\Delta[C_d \times A_f]_{ind} = \sum_{i=1}^{n} \Delta[C_d \times A_f]_i \quad (31)$$

where:

C_d is the aerodynamic drag coefficient;

A_f is the frontal area of the vehicle, m^2;

$\Delta[C_d \times A_f]_{ind}$ is the difference in aerodynamic drag between the individual vehicle and the test vehicle L, due to options on the vehicle that differ from those installed on the test vehicle L, m^2;

$\Delta[C_d \times A_f]_i$ is the aerodynamic drag difference by an individual feature i on the vehicle ($\Delta[C_d \times A_f]_i$ is positive for an option that adds aerodynamic drag with respect to test vehicle L and vice versa), m^2;

n is the number of options on the vehicle that are different between the individual and the test vehicle L.

The sum of all $\Delta[C_d \times A_f]_i$ between options installed on the test vehicles L and H shall correspond to the total difference between the $C_d \times A_f$ values for the test vehicles L and H, referred to as $\Delta[C_d \times A_f]_{LH}$.

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The sum of all $\Delta[C_d \times A_f]_i$, expressed as Δf_2, between options installed on the test vehicles L and H shall correspond to the difference in f_2 between the test vehicles L and H.

If the same options on the vehicle were also installed on test vehicles L and H, the value of $\Delta[C_d \times A_f]_{ind}$ for the interpolation method shall be set to zero.

3.2.3.2.2.4. Calculation of road load for individual vehicles in the CO_2 vehicle family

The road load coefficients f_0, f_1 and f_2 (as defined in Sub-Annex 4) for the test vehicles H and L are referred to as $f_{0,H}$, $f_{1,H}$ and $f_{2,H}$ and $f_{0,L}$, $f_{1,L}$ and $f_{2,L}$ respectively. An adjusted road load curve for the test vehicle L is defined as follows:

$$F_L(v) = f_{0,L}^* + f_{1,H} \cdot v + f_{2,L}^* \cdot v^2 \quad (32)$$

Applying the least squares regression method, adjusted road load coefficients $f_{0,L}^*$ and $f_{2,L}^*$ shall be determined for $F_L(v)$ with the linear coefficient $f_{1,L}^*$ set to $f_{1,H}$. The road load coefficients $f_{0,ind}$, $f_{1,ind}$ and $f_{2,ind}$ for the individual vehicle in the CO_2 vehicle family are calculated as follows:

$$f_{0,ind} = f_{0,H} - \Delta f_0 \times \frac{(TM_H \times RR_H - TM_{ind} \times RR_{ind})}{(TM_H \times RR_H - TM_L \times RR_L)} \quad (33)$$

or, if $(TM_H \times RR_H - TM_L \times RR_L) = 0$, the equation below shall apply:

$$f_{0,ind} = f_{0,H} - \Delta f_0 \quad (34)$$

$$f_{1,ind} = f_{1,H} \quad (35)$$

$$f_{2,ind} = f_{2,H} - \Delta f_2 \frac{(\Delta[C_d \times A_f]_{LH} - \Delta[C_d \times A_f]_{ind})}{(\Delta[C_d \times A_f]_{LH})} \quad (36)$$

or, if $\Delta[C_d \times A_f]_{LH} = 0$, the equation below shall apply:

$$f_{2,ind} = f_{2,H} - \Delta f_2 \quad (37)$$

where:

$$\Delta f_0 = f_{0,H} - f_{0,L}^* \quad (38)$$

$$\Delta f_2 = f_{2,H} - f_{2,L}^* \quad (39)$$

3.2.3.2.2.5. Calculation of cycle energy per phase

The cycle energy demand $E_{k,p}$ and distance $d_{c,p}$ per cycle phase p applicable for individual vehicles in the CO_2 vehicle family shall be calculated according to the procedure in paragraph 5. of this Sub-Annex, for the following sets k of road load coefficients and masses:

k=1: $f_0 = f_{0,L}^*$, $f_1 = f_{1,H}$, $f_2 = f_{2,L}^*$, $m = TM_L$ (40)

(test vehicle L)

k=2: $f_0 = f_{0,H}^*$, $f_1 = f_{1,H}$, $f_2 = f_{2,H}^*$, $m = TM_H$ (41)

(test vehicle H)

k=3: $f_0 = f_{0,ind}$, $f_1 = f_{1,H}$, $f_2 = f_{2,ind}^*$, $m = TM_{ind}$ (42)

(individual vehicle in the CO_2 vehicle family)

3.2.3.2.2.6. Calculation of the CO_2 value for an individual vehicle by the CO_2 interpolation method

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Comment [RCG165]: Added in GTR 20.05.14

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Comment [RCG166]: Editorial: Grammar issue. Two suggestions.

"for the following sets (k) of road load coefficients and masses"

or

"for the following sets of road load coefficients and masses (k)"

S.Dubuc looking into this.

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Comment [RCG167]: GTR OPEN POINT: 19.05.2014: It is possible that the superscript * in the f0 and f2 equations are false. Experts have been contacted.

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Comment [RCG168]: GTR OPEN POINT: 19.05.2014: It is possible that the superscript * in the f2 equation is false. Experts have been contacted.

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For each cycle phase p of the WLTC applicable for individual vehicles in the CO_2 vehicle family, the contribution to the total mass of CO_2 for the individual vehicle shall be calculated as follows:

$$M_{CO_2-ind,p} = M_{CO_2-L,p} + \left(\frac{E_{3,p}-E_{1,p}}{E_{2,p}-E_{1,p}}\right) \times \left(M_{CO_2-H,p} - M_{CO_2-L,p}\right) \quad (43)$$

The CO_2 mass emissions attributed to the individual vehicle of the CO_2 vehicle family M_{CO_2-ind} shall be calculated by the following equation:

$$M_{CO_2-ind} = \frac{\sum_p M_{CO_2-ind,p} \times d_{c,p}}{\sum_p d_{c,p}} \quad (44)$$

for all of the applicable cycle phases p.

3.3. Mass of particulate emissions

3.3.1. Calculation of particulate mass emissions using the double dilution method

Particulate emission M_p (g/km) is calculated as follows:

$$M_p = \frac{(V_{mix}+V_{ep}) \times P_e}{V_{ep} \times d} \quad (45)$$

where exhaust gases are vented outside tunnel;

and:

$$M_p = \frac{V_{mix} \times P_e}{V_{ep} \times d} \quad (46)$$

where exhaust gases are returned to the tunnel;

where:

V_{mix} is the volume of diluted exhaust gases (see paragraph 2. of this Sub-Annex), under standard conditions;

V_{ep} is the volume of diluted exhaust gas flowing through the particulate filter under standard conditions;

P_e is the particulate mass collected by one or more filters, mg;

d is the distance corresponding to the operating cycle, km;

M_p is the particulate emission, g/km.

3.3.1.1. Where correction for the particulate background level from the dilution system has been used, this shall be determined in accordance with paragraph 1.2.1.3.1. of Sub-Annex 6. In this case, the particulate mass (g/km) shall be calculated as follows:

$$M_p = \left\{\frac{P_e}{V_{ep}} - \left[\frac{P_a}{V_{ap}} \times \left(1 - \frac{1}{DF}\right)\right]\right\} \times \frac{(V_{mix}+V_{ep})}{d} \quad (47)$$

in the case where exhaust gases are vented outside tunnel;

$$M_p = \left\{\frac{P_e}{V_{ep}} - \left[\frac{P_a}{V_{ap}} \times \left(1 - \frac{1}{DF}\right)\right]\right\} \times \frac{(V_{mix})}{d} \quad (48)$$

in the case where exhaust gases are returned to the tunnel;

where:

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Comment [RCG169]: GTR OPEN POINT: 19.05.2014: Experts (C. Hosier/C. Vallaude) have been requested to confirm whether this is double dilution or not.

Comment [RCG170]: GTR EXPERT PROPOSAL: 19.05.2014: L. Hill believes the title should be "Calculation of particulate emissions" with no reference to double dilution.

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

P_a is the particulate mass of the dilution air, or the dilution tunnel background air, as determined by the one of the methods described in paragraph 1.2.1.3.1. of Sub-Annex 6;

DF is the dilution factor determined in paragraph 3.2.1.1.1. of this Sub-Annex.

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.

3.3.2. Calculation of particulate mass emissions using the double dilution method

$$V_{ep} = V_{set} - V_{ssd} \qquad (49)$$

where:

V_{ep} is the volume of diluted exhaust gas flowing through the particulate filter under standard conditions;

V_{set} is the volume of the double diluted exhaust gas passing through the particulate collection filters;

V_{ssd} is the volume of the secondary dilution air.

Where the secondary diluted PM sample gas is not returned to the tunnel, the CVS volume shall be calculated as in single dilution, i.e.:

$$V_{mix} = V_{mix\ indicated} + V_{ep} \qquad (50)$$

where $V_{mix\ indicated}$ is the measured volume of diluted exhaust gas in the dilution system following extraction of the particulate sample under standard conditions.

4. Determination of particle numbers

4.1. The number of particle emissions shall be calculated by means of the following equation:

$$N = \frac{V \times k \times (\overline{C_s} \times \overline{f_r} - C_b \times \overline{f_{rb}}) \times 10^3}{d} \qquad (51)$$

where:

N is the particle number emission, particles per kilometre;

V is the volume of the diluted exhaust gas in litres per test (after primary dilution only in the case of double dilution) and corrected to standard conditions (273.15 K and 101.325 kPa);

k is a calibration factor to correct the particle number counter measurements to the level of the reference instrument where this is not applied internally within the particle number counter. Where the calibration factor is applied internally within the particle number counter, the calibration factor shall be 1;

$\overline{C_s}$ is the corrected concentration of particles from the diluted exhaust gas expressed as the average number of particles per cubic centimetre figure from the emissions test including the full duration of the drive

Comment [RCG171]: New text from GTR 11.05.14 – incorporates recommendation from Les Hill, Horiba

GTR OPEN POINT: 11.05.2014: proposal from L. Hill.
Approval from experts requested.

Deleted: is the rolling average of the particulate mass collected from the dilution tunnel as specified in this gtr up to a maximum equivalent of 1mg/km at the same CVS and particulate sampling flow rates;

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cycle. If the volumetric mean concentration results $(\bar{C})$ from the particle number counter are not measured at standard conditions (273.15 K and 101.325 kPa), the concentrations shall be corrected to those conditions $(\bar{C}_s)$;

C_b is either the dilution air or the dilution tunnel background particle concentration, as permitted by the approval authority, in particles per cubic centimeter, corrected for coincidence and to standard conditions (273.15 K and 101.325 kPa);

f_r is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the test;

f_{rb} is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the background measurement;

d is the distance corresponding to the operating cycle, km

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

$$\bar{C} = \frac{\sum_{i=1}^{n} C_i}{n} \qquad (52)$$

where:

C_i is a discrete measurement of particle concentration in the diluted gas exhaust from the particle counter; particles per cubic centimetre and corrected for coincidence;

n is the total number of discrete particle concentration measurements made during the operating cycle and shall be calculated using the following equation:

$$n = t \times f \qquad (53)$$

where:

t is the time duration of the operating cycle, s;

f is the data logging frequency of the particle counter, Hz.

5. Calculation of cycle energy demand

Basis of the calculation is the target speed trace given in discrete time sample points t_i between t_{start} and t_{end}. In case of the Class 2 and Class 3 cycles, $t_{start} = 0$ second and $t_{end} = 1800$ seconds. For a specific cycle phase, t_{start} and t_{end} shall be taken from Sub-Annex 1.

For the calculation, each time sample point is interpreted as time period. The duration Δt of these periods depends on the sampling frequency (1 second for 1 Hz, 0.5 seconds for 2 Hz or 0.1 second for 10 Hz).

The total energy demand E for the whole cycle or a specific cycle phase shall be calculated by summing E_i over the corresponding cycle time between t_{start} and t_{end} according to the following equation:

$$E = \sum_{t_{start}}^{t_{end}} E_i \qquad (54)$$

where:

$$E_i = F_i \times d_i \qquad \text{if } F_i > 0 \qquad (55)$$

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Comment [RCG174]: "T" corrected to "t" in GTR 20.05.14
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$$E_i = 0 \qquad \text{if } F_i \leq 0 \qquad (56)$$

and:

E_i is the energy demand during time period (i-1) to (i), Ws;

F_i is the driving force during time period (i-1) to (i), N;

d_i is the distance travelled during time period (i-1) to (i), m.

$$F_i = f_0 + f_1 \times \left(\frac{v_i + v_{i-1}}{2}\right) + f_2 \times \frac{(v_i + v_{i-1})^2}{4} + (1.03 \times TM) \times a_i \qquad (57)$$

where:

F_i is the driving force during time period (i-1) to (i), N;

v_i is the target velocity at time t_i km/h;

TM is the test mass, kg;

a_i is the acceleration during time period (i-1) to (i), m/s²;

f_0, f_1, f_2 are the road load coefficients for the test vehicle under consideration (TM_L, TM_H or TM_{ind}) in N, N/km/h and in N/(km/h)² respectively.

$$d_i = \frac{(v_i + v_{i-1})}{2 \times 3.6} \times (t_i - t_{i-1}) \qquad (58)$$

where:

d_i is the distance travelled in time period (i-1) to (i), m;

v_i is the target velocity at time t_i, km/h;

t_i is time, s.

$$a_i = \frac{v_i - v_{i-1}}{3.6 \times (t_i - t_{i-1})} \qquad (59)$$

where:

a_i is the acceleration during time period (i-1) to (i), m/s²;

v_i is the target velocity at time t_i, km/h;

t_i is time, s.

6. Calculation of fuel consumption

6.1. The fuel characteristics required for the calculation of fuel consumption values shall be taken from Sub-Annex 3.

6.2. The fuel consumption values shall be calculated from the emissions of hydrocarbons, carbon monoxide, and carbon dioxide determined from the measurement results using the provisions defined in this Annex.

6.3. For a vehicle with a positive ignition engine fuelled with petrol (E0)

$$FC = \left(\frac{0.1154}{\rho}\right) * [(0.866 * HC) + (0.429 * CO) + (0.273 * CO_2)] \qquad (60)$$

6.4. For a vehicle with a positive ignition engine fuelled with petrol (E5)

$$FC = \left(\frac{0.118}{\rho}\right) * [(0.848 * HC) + (0.429 * CO) + (0.273 * CO_2)] \qquad (61)$$

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Comment [RCG175]: AdminWG 040414 – Align fuels with those in 692/2008 (but not H2NG)

For AdminWG 150514
Confirmed that hydrogen is needed.

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Comment [RCG176]: 250314 GTR Benchmark changes all the "*" for "x" in the equations that follow.

Comment [RCG177]: For AdminWG 150514
692/2008 and Reg 101 use "D" in the fuel consumption calculations

Comment [RCG178]: AdminWG 040414 – use the UNECE convention in this document

NB: R.83 uses at least the following symbols for multiply; "•" and "*".

To be discussed with Serge D

6.5. For a vehicle with a positive ignition engine fuelled with petrol (E10)

$$FC = \left(\frac{0.120}{\rho}\right) * [(0.830 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (62)$$

6.6. For a vehicle with a positive ignition engine fuelled with LPG

$$FC_{norm} = \left(\frac{0.1212}{0.538}\right) * [(0.825 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (63)$$

6.6.1. 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:

$$FC_{norm} = \left(\frac{0.1212}{0.538}\right) * cf * [(0.825 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (64)$$

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

$$Cf = 0.825 + 0.0693 \times n_{actual} \quad (65)$$

where:

n_{actual} is the actual H/C ratio of the fuel used.

6.7. For a vehicle with a positive ignition engine fuelled with NG/biomethane

$$FC_{norm} = \left(\frac{0.1336}{0.654}\right) * [(0.749 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (66)$$

6.8. For a vehicle with a compression engine fuelled with diesel (B0)

$$FC = \left(\frac{0.1155}{\rho}\right) * [(0.866 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (67)$$

6.9. For a vehicle with a compression engine fuelled with diesel (B5)

$$FC = \left(\frac{0.116}{\rho}\right) * [(0.861 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (68)$$

6.10. For a vehicle with a compression engine fuelled with diesel (B7)

$$FC = \left(\frac{0.116}{\rho}\right) * [(0.859 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (69)$$

6.11. For a vehicle with a positive ignition engine fuelled with ethanol (E85)

$$FC = \left(\frac{0.1742}{\rho}\right) * [(0.574 * HC) + (0.429 * CO) + (0.273 * CO_2)] \quad (70)$$

6.12 For a vehicle fuelled by gaseous hydrogen

$$FC = 0{,}024 \cdot \frac{V}{d} \cdot \left[\frac{1}{Z_2} \cdot \frac{p_2}{T_2} - \frac{1}{Z_1} \cdot \frac{p_1}{T_1}\right]$$

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

$FC = 0.1 \cdot (0.1119 \cdot H2O + H2)$

or a method according to standard protocols such as SAE J2572.

where for all equations in paragraph 6:

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Comment [RCG179]: Updated in 230414 GTR benchmark

Comment [RCG180]: AdminWG 150514 – Agreed that hydrogen should be added.

Need to create a new equation to match version copied in from EU 630/2012

Add new equation number/s

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Comment [RCG181]: Post AdminWG 150514 – Copied in from EU 630/2012 / Reg No 101.

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FC is the fuel consumption in litre per 100 km (in the case of petrol, ethanol, LPG, diesel or biodiesel) in m^3 per 100 km (in the case of natural gas) or in kg per 100 km in the case of hydrogen.;

HC are the measured emissions of hydrocarbons, g/km;

CO are the measured emissions of carbon monoxide, g/km;

CO_2 are the measured emissions of carbon dioxide, g/km;

H_2O the measured emission of H_2O in g/km;

H_2 the measured emission of H_2 in g/km; ρ is the density of the test fuel.

[EU 630/2012 INTRODUCES A LOT OF ADDITIONAL DETAIL HERE AS FOLLOWS IN THE BOX BELOW. NB: SOME RELATES TO H2NG SO WOULD NOT BE COPIED ACROSS.]

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.

p1 = pressure in gaseous fuel tank before the operating cycle in Pa;

p2 = pressure in gaseous fuel tank after the operating cycle in Pa;

T1 = temperature in gaseous fuel tank before the operating cycle in K.

T2 = temperature in gaseous fuel tank after the operating cycle in K.

Z1 = compressibility factor of the gaseous fuel at p1 and T1

Z2 = compressibility factor of the gaseous fuel at p2 and T2

V = inner volume of the gaseous fuel tank in m3

The compressibility factor shall be obtained from the following table:

[EU 630/2102 HAS TABLE OF FACTORS ADDED HERE. WE COULD X-REF TO THAT TABLE.]

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.

Comment [RCG182]: **m^3 per 100km**

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Comment [RCG183]: For AdminWG 200514

Raises the question as to whether, for Annex XXI, we should be repeating this information from elsewhere in the same regulation. Should we just be making lots of x-references?

Submitted by the European Commission

Informal document GRPE-69-16
69th GRPE, 5 – 6 June 2014
Agenda item 3a

Sub-Annex 8

Pure and hybrid electric vehicles

1. General requirements

In the case of testing NOVC-HEV and OVC-HEV vehicles, Appendix 2 to this Sub-Annex replaces Appendix 2 of Sub-Annex 6.

1.1. Energy balance

The energy balance shall be the sum of the ΔE_{REESS} of all rechargeable electric energy storage systems (REESS), i.e. the sum of the RCB values multiplied by the respective nominal V_{REESS} for each REESS.

1.2. Electric energy consumption and range testing

Parameters, units and accuracy of measurements shall be as in Table A8/1.

Table A8/1
Parameters, units and accuracy of measurements

Parameter	*Units*	*Accuracy*	*Resolution*
Electrical energy [(1)]	Wh	± 1 per cent	0.001 Wh[(2)]
Electrical current	A	± 0.3 per cent FSD or ± 1 per cent of reading [(3,4)]	0.01 A

(1) Equipment: static meter for active energy.
(2) AC watt-hour meter, Class 1 according to IEC 62053-21 or equivalent.
(3) Whichever is greater.
(4) Current integration frequency 10 Hz or more.

1.3. Emission and fuel consumption testing

Parameters, units and accuracy of measurements shall be the same as those required for conventional combustion engine-powered vehicles as found in Sub-Annex 5 (test equipment and calibrations).

1.4. Measurement units and presentation of results

The accuracy of measurement units and the presentation of the results shall follow the indications given in Table A8/2.

Table A8/2

Accuracy of measurement units and presentation of the results

Parameter	*Units*	*Communication of test result*
AER, AERcity	km	Rounded to nearest whole number
EAER	km	Rounded to nearest whole number
R_{CDA}	km	Rounded to nearest whole number
R_{CDC}	km	Rounded to nearest whole number
Distance	km	Rounded to nearest whole number; for calculation purposes: 0.1 km
Electric energy consumption	Wh/km	Rounded to nearest whole number
NEC	Wh	Rounded to first decimal place
NEC ratio	per cent	Rounded to first decimal place
E_{AC} recharge energy from the grid	Wh	Rounded to nearest whole number
FC correction factor	l/100 km/(Wh/km)	Rounded to 4 significant digits
CO_2 correction factor	g/km/(Wh/km)	Rounded to 4 significant digits
Utility factor		Rounded to 3 decimal places

1.5. Type 1 test cycles to be driven according to Table A8/3.

1.5.1. All OVC-HEVs, NOVC-HEVs and PEVs with and without driver-selectable operating modes shall be classified as Class 3 vehicles.1.5.1.1. OVC-HEV and PEV

1.5.1.1.1. WLTC test

1.5.1.1.1.1. Class 3a vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-1}$), a high phase ($High_{3-1}$) and an extra high phase (Extra $High_3$).

1.5.1.1.1.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-2}$), a high phase ($High_{3-2}$) and an extra high phase (Extra $High_3$).

1.5.1.1.2. WLTC city test

1.5.1.1.2.1. Class 3a vehicles shall drive a cycle consisting of a low phase (Low_3) and a medium phase ($Medium_{3-1}$)

1.5.1.1.2.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low_3) and a medium phase ($Medium_{3-2}$)

1.5.1.2. NOVC-HEV

1.5.1.2.1. WLTC test

1.5.1.2.1.1. Class 3a vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-1}$), a high phase ($High_{3-1}$) and an extra high phase (Extra $High_3$).

Comment [RCG184]: Update from GTR 03.04.2014

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Comment [RCG185]: AdminWG 040414 – P. Öhlund confirmed deletion. The text was included in the GTR for Japan.

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1.5.1.2.1.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-2}$), a high phase ($High_{3-2}$) and an extra high phase (Extra $High_3$).

Table A8/3

Test matrix

		WLTP		WLTP city
		Criteria Emissions, FC, CO_2, AER, EAER, R_{CDC}, R_{CDA}, E_{AC}	*Criteria Emissions, FC, CO_2*	*AERcity, E_{AC}city*
		Charge-depleting	*Charge-sustaining*	*Charge-depleting*
OVC-HEV	Class 3a	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + ($ExtraHigh_3$)	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + ($ExtraHigh_3$)	Low_3 + $Medium_{3-1}$
	Class 3b	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + ($ExtraHigh_3$)	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + ($ExtraHigh_3$)	Low_3 + $Medium_{3-2}$
NOVC-HEV	Class 3a	--	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + ($ExtraHigh_3$)	--
	Class 3b	--	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + ($ExtraHigh_3$)	--
PEV	Class 3a	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + ($ExtraHigh_3$)	--	Low_3 + $Medium_{3-1}$
	Class 3b	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + ($ExtraHigh_3$)	--	Low_3 + $Medium_{3-2}$

1.6. OVC-HEVs. NOVC-HEVs and PEVs with manual transmissions shall be driven according to the manufacturer's instructions, as incorporated in the manufacturer's handbook of production vehicles and indicated by a technical gear shift instrument.

2. REESS Preparation

2.1. For all OVC-HEVs, NOVC-HEVs, and PEVs with and without driver-selectable operating modes, the following shall apply:

(a) Without prejudice to the requirements of paragraph 1.2.3.3. of Sub-Annex 6, the vehicles tested to this Sub-Annex must have been driven at least 300 km with those batteries installed in the test vehicle;

(b) 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 REESS in its normal operating range. The manufacturer shall provide evidence that the thermal management system of the REESS is neither disabled nor reduced.

3. Test procedure

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Comment [RCG186]: AdminWG 040414 – P. Öhlund confirmed deletion. The text was included in the GTR for Japan.

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3.1. General requirements

3.1.1. For all OVC-HEVs, NOVC-HEVs, and PEVs with and without driver-selectable operating modes, the following shall apply where applicable:

3.1.1.1. Vehicles shall be conditioned, soaked and tested according to the test procedures applicable to vehicles powered solely by a combustion engine described in Sub-Annex 6 unless modified by this Sub-Annex.

3.1.1.2. If the vehicles cannot follow the speed trace, the acceleration control shall be fully activated until the required speed trace is reached again. Power to mass calculations and classification methods shall not apply to these vehicle types.

3.1.1.3. The vehicle shall be started by the means provided for normal use to the driver.

3.1.1.4. Exhaust emission sampling and electricity measuring shall begin for each test cycle before or at the initiation of the vehicle start up procedure and end on conclusion of each test cycle.

3.1.1.5. Emissions compounds shall be sampled and analysed for each individual WLTC phase when the combustion engine starts consuming fuel.

3.1.2. Forced cooling as per paragraph 1.2.7.2. of Sub-Annex 6 shall apply only for the charge-sustaining test and for the testing of NOVC-HEVs.

3.2. OVC-HEV, with and without driver-selectable operating modes

3.2.1. Vehicles shall be tested under charge-depleting (CD) and charge-sustaining (CS) conditions according to the cycles described in paragraph 1.5.1.1.1. of this Sub-Annex.

3.2.2. Vehicles may be tested according to four possible test sequences:

3.2.2.1. Option 1: charge-depleting test with a subsequent charge-sustaining test (CD + CS test).

3.2.2.2. Option 2: charge-sustaining test with a subsequent charge-depleting test (CS + CD test).

3.2.2.3. Option 3: charge-depleting test with no subsequent charge-sustaining test (CD test).

3.2.2.4. Option 4: charge-sustaining test with no subsequent charge-depleting test (CS test).

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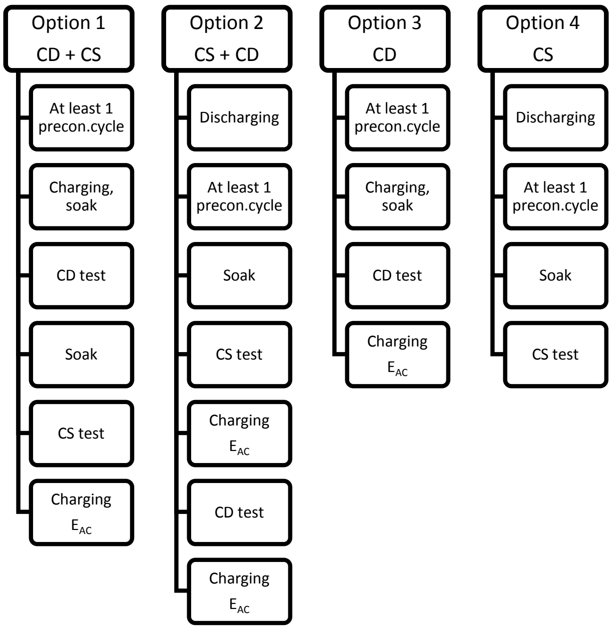
Figure A8/1

Possible test sequences in case of OVC-HEV testing



3.2.3. The driver selectable operating mode switch shall be set according to the test conditions.

3.2.4. Charge-depleting (CD) test with no subsequent charge-sustaining (CS) test (Option 3)

3.2.4.1. Preconditioning

The vehicle shall be prepared according to the procedures in paragraph 2.2. of Appendix 4, to this Sub-Annex.

3.2.4.2. Test conditions

3.2.4.2.1. The test shall be carried out with a fully charged REESS according the charging requirements as described in paragraph 2.2.5. of Appendix 4 to this Sub-Annex.

3.2.4.2.2. Operation mode selection

3.2.4.2.2.1. The charge-depleting test shall be performed in the highest electric energy consumption mode that best matches the driving cycle. If the vehicle cannot follow the trace, other installed propulsion systems shall be used to allow the vehicle to best follow the cycle.

3.2.4.2.2.2. Dedicated driver-selectable modes such as "mountain mode" or "maintenance mode" which are not intended for normal daily operation but only for special limited purposes shall not be considered for charge-depleting condition testing.

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3.2.4.3. Type 1 test procedure

3.2.4.3.1. The charge-depleting test procedure shall consist of a number of consecutive cycles, each followed by a soak period of no more than 30 minutes until charge-sustaining operation is achieved.

3.2.4.3.2. During soaking between individual WLTCs, the key switch shall be in the "off" position, and the REESS shall not be recharged from an external electric energy source. The RCB instrumentation shall not be turned off between test cycle phases. In the case of ampere-hour meter measurement, the integration shall remain active throughout the entire test until the test is concluded.

Restarting after soak, the vehicle shall be operated in the required driver-selectable operation mode.

3.2.4.3.3. In deviation from paragraph 5.3.1. of Sub-Annex 5 and without prejudice to paragraph 5.3.1.2. analysers may be calibrated and zero checked before and after the charge-depleting test.

3.2.4.4. End of the charge-depleting test

The end of the charge-depleting test is considered to have been reached at the end of WLTC n (defined as the transition cycle) when the break-off criterion during cycle n + 1 is reached for the first time.

3.2.4.4.1. For vehicles without charge-sustaining capability on the complete WLTC, end of test is reached by an indication on a standard on-board instrument panel to stop the vehicle, or when the vehicle deviates from the prescribed driving tolerance for 4 seconds or more. The acceleration controller shall be deactivated. The vehicle shall be braked to a standstill within 60 seconds.

3.2.4.5. Break-off criterion

3.2.4.5.1. The break-off criterion for the charge-depleting test is reached when the relative net energy change, NEC, as shown in the equation below is less than 4 per cent.

$$NEC\ (\%) = \left(\frac{RCB \times \text{nominal REESS voltage}}{\text{test vehicle cycle energy demand}}\right) < 4\ \% \qquad (1)$$

where:

NEC is the net energy change, per cent;

RCB is the REESS charge balance, Ah;

Nominal REESS voltage is the voltage of an electrochemical system according to DIN EN 60050-482.

3.2.4.6. REESS charging and measuring electric energy consumption

The vehicle shall be connected to the mains within 120 minutes after the conclusion of the charge-depleting Type 1 test. The energy measurement equipment, placed before the vehicle charger, shall measure the charge energy, E_{AC}, delivered from the mains, as well as its duration. Electric energy measurement can be stopped when the state of charge after the CD test is at least equal to the state of charge measured before the CD test. The state of charge can be determined by on-board or external instruments.

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3.2.4.7. Each individual full WLTC within the charge-depleting test shall fulfil the applicable exhaust emission limits according to paragraph 1.1.1.2. of Sub-Annex 6.

3.2.5. CS test with no subsequent CD test (Option 4)

3.2.5.1. Preconditioning

The vehicle shall be prepared according to the procedures in paragraph 2.1. of Appendix 4 to this Sub-Annex.

3.2.5.2. Test conditions

3.2.5.2.1. Tests shall be carried out with the vehicle operated in charge-sustaining operation condition in which the energy stored in the REESS may fluctuate but, on average, is maintained at a charging neutral balance level while the vehicle is driven.

3.2.5.2.2. For vehicles equipped with a driver-selectable operating mode, the charge-sustaining test shall be performed in the charging balance neutral hybrid mode that best matches the target curve.

3.2.5.2.3. The profile of the state of charge of the REESS during different stages of the Type 1 test in CD and CS mode respectively is given in Appendices 1a and 1b of this Sub-Annex.

3.2.5.2.4. Upon request of the manufacturer and with approval of the approval authority, the manufacturer may set the start state of charge of the traction REESS for the charge-sustaining test.

3.2.5.3. Type 1 test procedure

3.2.5.3.1. If required by paragraph 4.2.1.3. of this Sub-Annex, CO_2, emissions and fuel consumption results shall be corrected according to the RCB correction as described in Appendix 2 of this Sub-Annex.

3.2.5.3.2. The charge-sustaining test shall fulfil the applicable exhaust emission limits according to paragraph 1.1.1.2. of Sub-Annex 6.

3.2.6. CD test with a subsequent CS test (Option 1)

3.2.6.1. The procedures for the CD test from paragraph 3.2.4.1. up to and including paragraph 3.2.4.5. of this Sub-Annex shall be followed.

3.2.6.2. Subsequently, the procedures for the CS test from paragraph 3.2.5.1. up to and including paragraph 3.2.5.3. (except paragraph 3.2.5.2.4.) in this Sub-Annex shall be followed.

3.2.6.3. REESS charging and measuring electric energy consumption

The vehicle shall be connected to the mains within 120 minutes after the conclusion of the charge-sustaining Type 1 test. The energy measurement equipment, placed before the vehicle charger, shall measure the charge energy, E, delivered from the mains, as well as its duration. Electric energy measurement may be stopped when the state of charge after the CS test is at least equal to the state of charge measured before the CD test. The state of charge shall be determined by on-board or external instruments.

3.2.7. CS test with a subsequent CD test (Option 2)

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3.2.7.1. The procedures for the CS test from paragraph 3.2.5.1. to paragraph 3.2.5.3. and paragraph 3.2.6.3. in this Sub-Annex shall be followed.

3.2.7.2. Subsequently, the procedures for the CD test from paragraph 3.2.4.3. to paragraph 3.2.4.7. of this Sub-Annex shall be followed.

3.2.8. Cycle energy demand

3.2.8.1. Cycle energy demand of the test vehicle shall be calculated according to paragraph 5 of Sub-Annex 7.

3.2.9. Electric range determination

3.2.9.1. The charge-depleting test procedure as described in paragraph 3.2.4. of this Sub-Annex shall apply to electric range measurements.

3.2.9.2. All-electric range (AER, AERcity)

3.2.9.2.1. The total distance travelled over the test cycles from the beginning of the charge-depleting test to the point in time during the test when the combustion engine starts to consume fuel shall be measured.

3.2.9.3. Equivalent all-electric range (EAER)

3.2.9.3.1. The range shall be calculated according to paragraph 4.4.1.2. below.

3.2.9.4. Charge-depleting cycle range (R_{CDC})

3.2.9.4.1. The distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criteria shall be measured. This shall include the distance travelled during the transition cycle where the vehicle operates in both depleting and sustaining modes. If the charge-depleting test possesses a transition range, the R_{CDC} shall include those transition cycles or cycles.

3.2.9.5. Actual charge-depleting range (R_{CDA})

3.2.9.5.1. The range shall be calculated according to paragraph 4.4.1.4. below.

3.3. NOVC-HEV, with and without driver-selectable operating modes

3.3.1. Vehicles shall be tested under charge-sustaining (CS) conditions according to the cycles described in paragraph 1.5.1.2.1. of this Sub-Annex.

3.3.2. Vehicle and REESS Conditioning

3.3.2.1. Alternatively, at the request of the manufacturer, the level of the state of charge of the traction REESS for the charge-sustaining test may be set according to manufacturer's recommendation in order to achieve a charge balance neutral charge-sustaining test.

3.3.3. Type 1 Test

3.3.3.1. If required by paragraph 4.2.2. of this Sub-Annex, CO_2 emissions and fuel consumption results shall be corrected according to the RCB correction described in Appendix 2 to this Sub-Annex.

3.4. PEV, with and without driver-selectable operating mode

3.4.1. Vehicles shall be tested under charge-depleting (CD) conditions according to the cycles described in paragraph 1.5.1.1. of this Sub-Annex.

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Comment [RCG192]: AdminWG 040414 - P. Öhlund confirmed that this was not an option in the EU and should therefore be deleted

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3.4.2. The total distance travelled over the test cycles from the beginning of the charge-depleting test until the break-off criterion is reached shall be included in the test report.

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3.4.3. Breaks for the driver and/or operator shall be permitted only between test cycles as described in Table A8/4.

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Table A8/4
Breaks for the driver and/or test operator

Distance driven (km)	*Maximum total break time (min)*
Up to 100	10
Up to 150	20
Up to 200	30
Up to 300	60
More than 300	Shall be based on the manufacturer's recommendation

Note: during a break, the propulsion system switch shall be in the "OFF" position.

3.4.4. Testing

3.4.4.1. If the vehicle is equipped with a driver-selectable operating mode, the charge-depleting test shall be performed in the highest electric energy consumption mode that best matches the speed trace.

3.4.4.2. The measurement of all-electric range AER and electric energy consumption shall be performed during the same test.

3.4.4.3. All-electric range test

3.4.4.3.1. The test method shall include the following steps:

(a) Initial charging of the traction REESS;

(b) Driving consecutive WLTCs until the break-off criterion is reached and measuring AER;

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(c) Recharging the traction REESS and measuring the electric energy consumption.

3.4.4.3.1.1. The all-electric range test shall be carried out with a fully charged traction REESS according to the charging requirements as described in paragraph 3. of Appendix 4 to this Sub-Annex.

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3.4.4.3.1.2. WLTCs shall be driven and the all-electric range (AER) distance shall be measured.

3.4.4.3.1.3. The end of the test occurs when the break-off criterion is reached.

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The break-off criterion shall have been reached when the vehicle deviates from the prescribed driving tolerance for 4 seconds or more. The acceleration controller shall be deactivated. The vehicle shall be braked to a standstill within 60 seconds.

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3.4.4.3.1.4. The vehicle shall be connected to the mains within 120 minutes after the conclusion of the all-electric range AER determination. The energy measurement equipment, placed before the vehicle charger, shall measure the

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charge energy, E_{AC}, delivered from the mains, as well as its duration. Electric energy measurement may be stopped when the state of charge after the range test is at least equal to the state of charge measured before the range test. The state of charge shall be determined by on-board or external instruments.

3.4.4.4. All-electric range city (AERcity) test

3.4.4.4.1. The test method includes the following steps:

(a) Initial charging of the traction REESS;

(b) Driving consecutive WLTC city cycles until the break-off criterion is reached and measuring AERcity;

(c) Recharging the traction REESS and measuring electric energy

3.4.4.4.1.1.

The all-electric range city test shall be carried out with a fully charged traction REESS according to the charging requirements as described in paragraph 3. of Appendix 4 to this Sub-Annex.

3.4.4.4.1.2. City cycles shall be driven and the all-electric range city (AERcity) distance shall be measured.

3.4.4.4.1.3. The end of the test occurs when the break-off criterion is reached according to paragraph 3.4.4.3.1.3. above.

4. Calculations

4.1. Emission compound calculations

Exhaust gases shall be analysed according to Sub-Annex 6. All equations shall apply to WLTC tests.

4.1.1. OVC-HEV with and without operating mode switch

4.1.1.1. Charge-depleting mode emissions

The level of the emission compounds at charge-depleting, $M_{i,CD}$, shall be calculated as follows:

$$M_{i,CD} = \frac{\sum_{j=1}^{k}(UF_j * M_{i,CD,j})}{\sum_{j=1}^{k} UF_j} \qquad (2)$$

where:

$M_{i,CD,j}$ is the mass of the emissions compound measured during the j^{th} phase, g/km;

i is the emissions compound;

UF_j is the fractional utility factor of the j^{th} phase;

j is the index number of the phases up to the end of the transition cycle n:

k is the number of phases driven until the end of transition cycle n.

4.1.1.2. Charge-sustaining mode emissions

4.1.1.2.1. The charging balance correction (RCB) calculation is not required for the determination of emissions compounds.

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Comment [RCG193]: Post AdminWG 040414 – should it be 3.4.4.3.1.3. – as in para 3.4.4.4.1.3.?

AdminWG 080514 – update provided by P. Öhlund.

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4.1.1.3. Weighted emissions compounds

The weighted emissions compounds $M_{i,weighted}$, from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$M_{i,weighted} = \sum_{j=1}^{k}(UF_j * M_{i,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * M_{i,CS} \quad (3)$$

where:

$M_{i,weighted}$ is the utility factor-weighted exhaust emissions of each measured emission compound, g/km;

i is the emissions compound;

UF_j is the fractional utility factor of the j^{th} phase;

$M_{i,CD,j}$ are the compound mass emissions measured during the j^{th} charge-depleting phase, g/km;

$M_{i,CS}$ are the compound mass emissions for the charge-sustaining test according to paragraph 3.2.5., g/km;

j is the index number of the phases up to the end of the transition cycle n;

k is the number of phases driven until the end of transition cycle n.

4.1.2. NOVC-HEV with and without driver-selectable operating modes

4.1.2.1. Exhaust emissions shall be calculated as required for conventional vehicles according to Sub-Annex 7.

4.1.2.2. The charging balance correction (RCB) calculation is not required for the determination of emissions compounds.

4.2. CO_2 and fuel consumption calculations

Exhaust gases shall be analysed according to Sub-Annex 6.

4.2.1. OVC-HEV with and without an operating mode switch

All equations shall apply to the WLTC tests.

4.2.1.1. Weighted charge-depleting CO_2 emissions

The CO_2 values at charge-depleting, $CO_{2,CD}$, shall be calculated as follows:

$$CO_{2,CD} = \sum_{j=1}^{k}(UF_j * CO_{2,CD,j}) / \sum_{j=1}^{k} UF_j \quad (4)$$

where:

$CO_{2,CD}$ is the utility factor-adjusted mass of CO_2 emissions during charge-depleting mode, g/km;

$CO_{2,CD,j}$ are the CO_2 emissions measured during the j^{th} charge-depleting phase, g/km;

UF_j the driving cycle and phase-specific utility factor according to Appendix 5 to this Sub-Annex;

j is the index number of each phase up to the end of the transition cycle n;

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Comment [RCG196]: GTR OPEN POINT: 19.05.2014: Are these weighted emissions or not? EV experts have been contacted.

Comment [RCG197]: GTR EXPERT PROPOSAL: 20.05.2014: Kobayashi-san says "Weighted" means "calculated with Utility Factor". Therefore "weighted" is necessary. Comments from any other expert are welcome.

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k is the number of phases driven up to the end of transition cycle n.

4.2.1.2. Weighted charge-depleting fuel consumption

The fuel consumption values, FC_{CD}, at charge-depleting shall be calculated as follows:

$$FC_{CD} = \sum_{j=1}^{k}(UF_j * FC_{CD,j}) / \sum_{j=1}^{k} UF_j \qquad (5)$$

where:

FC_{CD} is the utility factor-adjusted fuel consumption charge-depleting mode, l/100 km;

$FC_{CD,j}$ is the fuel consumption measured during the j^{th} charge-depletion phase, l/100 km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this Sub-Annex;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.2.1.3. Charge-sustaining fuel consumption and CO_2 emissions

4.2.1.3.1. Test result correction as a function of REESS charging balance

The corrected values $CO_{2,CS,corrected}$ and $FC_{CS,corrected}$ shall correspond to a zero charging balance (RCB = 0), and shall be determined according to Appendix 2 to this Sub-Annex.

4.2.1.3.2. The electricity balance, measured using the procedure specified in Appendix 3 to this Sub-Annex, shall be used as a measure of the difference in the vehicle REESS' energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance shall be determined for the WLTC driven.

4.2.1.3.3. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:

(a) The manufacturer can prove that there is no relation between the energy balance and CO_2 emissions/fuel consumption;

(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging,

(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging. ΔE_{REESS}, expressed as a percentage of the energy content of the fuel consumed over the cycle, shall be calculated using the equation below:

$$\Delta E_{REESS} = \frac{0.0036 \times RCB \times U_{REESS}}{E_{Fuel}} \times 100\% \qquad (6)$$

where:

ΔE_{REESS} is the change in the REESS energy content, per cent;

U_{REESS} is the nominal REESS voltage, V;

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RCB is REESS charging balance over the whole cycle, Ah;

E_{Fuel} is the energy content of the consumed fuel, Wh.

ΔE_{REESS} is lower than the RCB correction criteria, according to the equation below and Table A8/5:

$\Delta E_{REESS} \leq$ RCB correction criterion

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Table A8/5
RCB correction criteria

Cycle	*WLTC (Low + Medium + High)*	*WLTC (Low + Medium + High + Extra High)*
RCB correction criterion (%)	1	0.5

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4.2.1.4. Weighted CO_2 emissions

The weighted CO_2 emissions from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

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$$CO_{2,weighted} = \sum_{j=1}^{k}(UF_j * CO_{2,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * CO_{2,CS} \quad (7)$$

where:

$CO_{2,weighted}$ are the utility factor-weighted CO_2 emissions, g/km;

UF_j is the fractional utility factor of the j^th phase;

$CO_{2,CD,j}$ are the CO_2 emissions measured during the j^th charge-depleting phase, g/km;

$CO_{2,CS}$ are the CO_2 emissions for the charge-sustaining test according to paragraph 4.2.1.3. above, g/km;

j is the index number of each phase up to the end of the transition cycle n;

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k is the number of phases driven up to the end of transition cycle n.

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4.2.1.5. Weighted fuel consumption

The weighted fuel consumption from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

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$$FC_{weighted} = \sum_{j=1}^{k}(UF_j * FC_{CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * FC_{CS} \quad (8)$$

where:

$FC_{weighted}$ is the utility factor-weighted fuel consumption, l/100 km;

UF_j is the fractional utility factor of the j^th phase;

$FC_{CD,j}$ is the fuel consumption measured during the j^th charge-depleting phase, l/100 km;

FC_{CS} is the fuel consumption measured during the charge-sustaining test according to paragraph 4.2.1.3. above, l/100 km;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.2.2. NOVC-HEV with and without driver-selectable operating modes

4.2.2.1. Exhaust gases shall be analysed according to Sub-Annex 6.

4.2.2.2. Charge-sustaining fuel consumption and CO_2 emissions shall be calculated according to paragraph 4.2.1.3. of this Sub-Annex.

4.2.2.3. Test result correction as a function of REESS charging balance

The corrected values $CO_{2,CS,corrected}$ and $FC_{CS,corrected}$ shall correspond to a zero energy balance (RCB = 0), and shall be determined according to Appendix 2 to this Sub-Annex.

4.2.2.3.1. The electricity balance, measured using the procedure specified in Appendix 3 to this Sub-Annex, shall be used as a measure of the difference in the vehicle REESS' energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance shall be determined for the WLTC driven.

4.2.2.3.2. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:

(a) The manufacturer can prove that there is no relation between the energy balance and fuel consumption;

(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging;

(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging. ΔE_{REESS}, expressed as a percentage of the energy content of the fuel consumed over the cycle, shall be calculated using the equation below:

$$\Delta E_{REESS} = \frac{0.0036 \times \sum_{i=1}^{z}(RCB_i \times U_{REESSi})}{E_{fuel}} \times 100 \qquad (9)$$

where:

U_{REESSi} is the nominal REESS voltage for i^{th} REESS, V;

RCB_i is the charging balance over the whole cycle for the i^{th} REESS, Ah;

E_{fuel} is the energy content of the consumed fuel, MJ.

i index of REESS

z number of installed REESS

ΔE_{REESS} is smaller than the RCB correction criteria, according to the following equation and Table A8/6 :

$\Delta E_{REESS} \leq$ RCB correction criterion

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Table A8/6
RCB correction criteria

Cycle	*WLTC (Low + Medium + High)*	*WLTC (Low + Medium + High + Extra High)*
RCB correction criterion (%)	1	0.5

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4.2.2.3.3. Where RCB corrections of CO_2 and fuel consumption measurement values are required, the procedure described in Appendix 2 to this Sub-Annex shall be used.

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4.3. Electric energy consumption calculations

4.3.1. OVC-HEV

4.3.1.1. Utility factor-weighted total AC electric energy consumption including charging losses shall be calculated using the following equations:

Comment [RCG204]: 250314 GTR Benchmark changes "*" to "x" in equations

$$EC_{weighted} = \sum_{j=1}^{k}(UF_j * EC_{CD,j}) \quad (10)$$

$$EC_{CD,j} = \frac{RCB_j}{d_j * \sum_{j=1}^{k} RCB_j} * E_{AC} \quad (11)$$

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where:

$EC_{weighted}$ is the utility factor-weighted total energy consumption, Wh/km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this Sub-Annex;

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$EC_{CD,j}$ is the calculated fraction of E_{AC} used in the j^{th} phase during the charge-depleting test, Wh/km;

RCB_j is the measured charge balance of the traction REESS of the j^{th} phase during the charge-depleting test, Ah;

d_j is the distance driven in the j^{th} phase during the charge-depleting test, km;

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Comment [RCG205]: "D" for distance replaced with "d" to match GTR convention. (x2).

E_{AC} is the measured recharged electric energy from the mains, Wh;

j is the index number of each phase up to the end of transition cycle n;

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k is the number of phases driven up to the end of transition cycle n.

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4.3.1.2. Electric energy consumption including charging losses

4.3.1.2.1. Recharged electric energy E in Wh and charging time measurements shall be included in the test report.

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4.3.1.2.2. Electric energy consumption EC is defined by the equation:

$$EC = E_{AC}/EAER \quad (12)$$

where:

EC	is the electric energy consumption, Wh/km;
E_{AC}	is the recharged electric energy from the mains, Wh;
EAER	is the equivalent all-electric range according to paragraph 4.4.1.2. below, km.

4.3.1.3. Charge-depleting AC electric energy consumption, EC_{CD}, including charging losses

$$EC_{CD} = \frac{EC_{weighted}}{\sum_{j=1}^{k} UF_j} \qquad (13)$$

where:

$EC_{weighted}$	is the electric energy consumption, Wh/km;
EC_{CD}	is the recharged electric energy from the grid including charging losses, Wh;
UF_j	is the driving cycle and phase-specific utility factor according to Appendix 5 to this Sub-Annex;
j	is the index number of each phase up to the end of transition cycle n;
k	is the number of phases driven up to the end of transition cycle n.

4.3.2. Pure electric vehicle (PEV)

4.3.2.1. Recharged electric energy E in Wh and charging time measurements shall be included in the test report.

4.3.2.2. The electric energy consumption EC including charging losses is defined by the equation:

$$EC = E_{AC}/AER \qquad (14)$$

where:

EC	is the electric energy consumption, Wh/km;
E_{AC}	is the recharged electric energy from the mains, Wh;
AER	is the all-electric range as defined in paragraph 4.4.2.1. of this Sub-Annex.

4.4. Electric Range

4.4.1. OVC-HEV

4.4.1.1. All-electric range, AER, and all-electric range city, AERcity

The distance driven over consecutive test cycles according to paragraph 1.5.1.1. of this Sub-Annex using only the REESS until the combustion engine starts consuming fuel for the first time shall be measured and be rounded to the nearest whole number.

4.4.1.2. Equivalent all-electric range, EAER

4.4.1.2.1. EAER shall be calculated as follows:

$$EAER = \left(\frac{CO_{2,CS} - CO_{2,CDavg}}{CO_{2,CS}}\right) * R_{CDC} \qquad (15)$$

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Comment [RCG207]: 250314 GTR Benchmark changes "*" to "x" in equation

where:

$$CO_{2,CD,avg} = \frac{\sum_{j=1}^{k} CO_{2,CD,j}}{\sum_{j=1}^{k} d_j} \quad (16)$$

and:

EAER is the equivalent all-electric range EAER, km;

$CO_{2,CS}$ are the CO_2 emissions during the charge-sustaining test, g/km;

$CO_{2,CD,j}$ are the CO_2 emissions in the j^{th} phase during the charge-depleting test, g;

d_j is the distance driven in the j^{th} phase during the charge-depleting test, km;

R_{CDC} is the charge-depleting cycle range, km;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of the transition cycle n.

4.4.1.3. Charge-depleting cycle range (R_{CDC})

The distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criterion shall be measured. This shall include the distance travelled during the transition cycle where the vehicle operates in both depleting and sustaining modes. If the charge-depleting test possesses a transition range, the R_{cdc} shall include those transition cycles or cycles.

4.4.1.4. Actual charge-depleting cycle range (R_{CDA})

$$R_{CDA} = \sum_{j=1}^{n-1} d_{j,cycle} + \left(\frac{CO_{2,CS} - CO_{2,n,cycle}}{CO_{2,CS} - CO_{2,CD,average,n-1}}\right) \times d_n \quad (17)$$

where:

R_{CDA} is the actual charge-depleting range, km;

$CO_{2,CS}$ are the CO_2 emissions during the charge-sustaining test, g/km;

$CO_{2,n,cycle}$ are the CO_2 emissions over the n^{th} drive cycle in charge-depleting operating condition, g/km;

$CO_{2,CD,average,n-1}$ are the average CO_2 emissions in charge-depleting operating condition until the n-1th drive cycle, g/km;

$d_{j,cycle}$ is the test distance travelled during j^{th} drive cycle, km;

d_n is the test distance travelled during the n^{th} drive cycle in charge-depleting operating condition, km;

j is the index number of each whole cycle up to the end of the transition cycle n;

n is the number of whole cycles driven including the transition cycle n.

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Comment [RCG208]: "D" for distance replaced with "d" to match GTR convention. (x2).

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Comment [RCG209]: "D" for distance replaced with "2 d" to match GTR convention. (x4).

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4.4.2. PEV

4.4.2.1. All-electric range, AER

The distance driven over consecutive WLTCs until the break-off criterion according to paragraph 3.4.4.3.1.3. above is reached shall be measured and be rounded to the nearest whole number.

4.4.2.2. All-electric city range, AERcity

The distance driven over consecutive WLTC city cycles until the break-off criterion according to paragraph 3.4.4.3.1.3. above is reached shall be measured and be rounded to the nearest whole number.

[RESERVED : Combined approach]

Comment [RCG210]: Post AdminWG 040414 – it should be 3.4.4.3.1.3.

Also, why is the equivalent text no longer in 4.4.2.2.?

AdminWG 080514 – updates provided by P. Öhlund.

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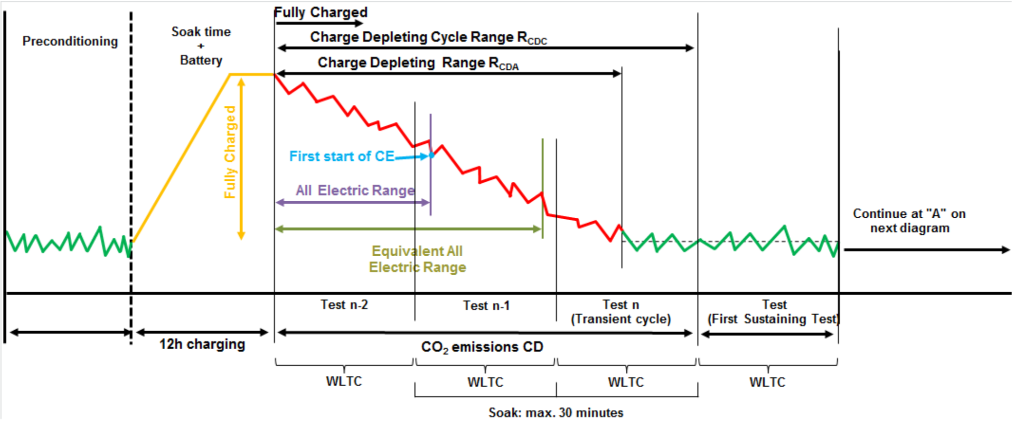
Sub-Annex 8 - Appendix 1a

RCB profile OVC-HEV, charge-depleting and charge-sustaining tests

1. RCB profile OVC-HEV, charge-depleting test (Figure A8.App1a/1) followed by a charge-sustaining test (Figure A8.App1a/2)

Figure A8.App1a/1

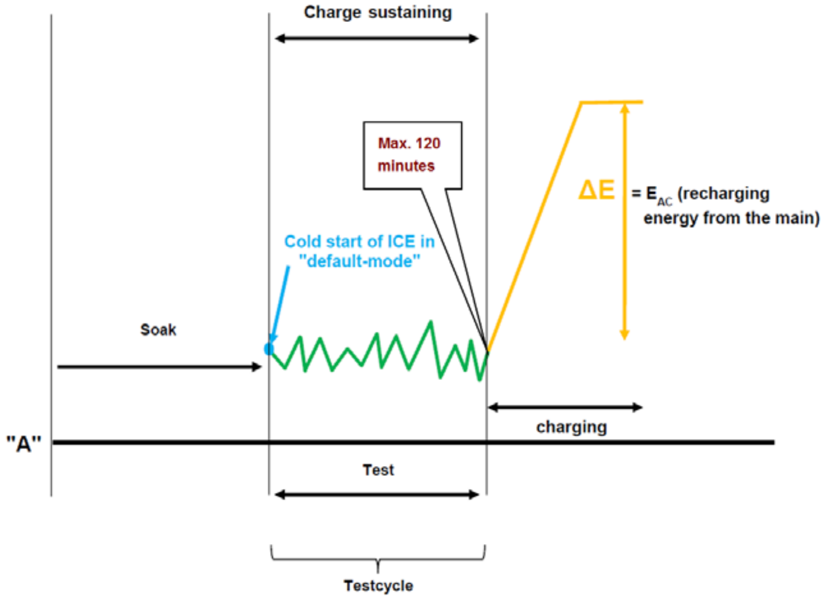
OVC-HEV, charge-depleting test



2. RCB profile OVC-HEV, charge-sustaining test (Figure A8.App1a/2) preceded by a charge-depleting test (Figure A8.App1a/1)

Figure A8.App1a/2

OVC-HEV, charge-sustaining test



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Sub-Annex 8 -Appendix 1b

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RCB profile, OVC-HEV and NOVC-HEV charge-sustaining test

1. RCB profile OVC-HEV, charge-sustaining test (Figure A8.App1b/1)

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Figure A8.App1b/1

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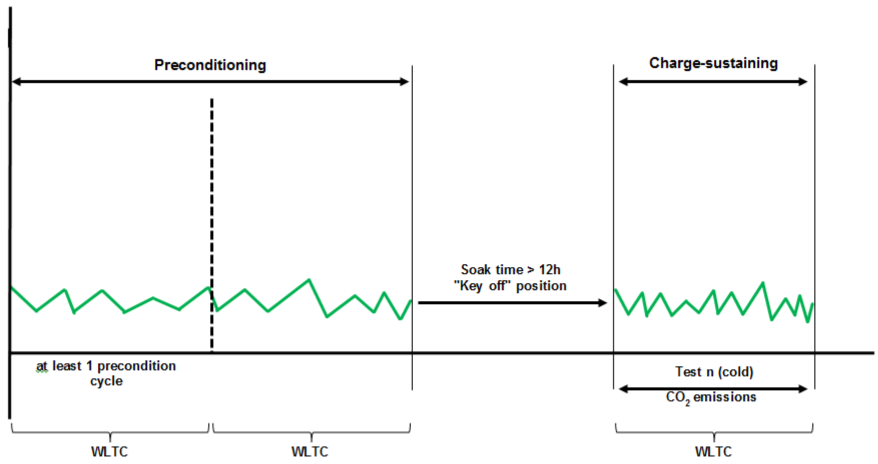
OVC-HEV, charge-sustaining test



Sub-Annex 8 -Appendix 1c

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RCB profile, PEV, electric range and electric energy consumption test

1. RCB profile, PEV, electric range and electric energy consumption test (Figure A8.App1c/1)

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Figure A8.App1c/1

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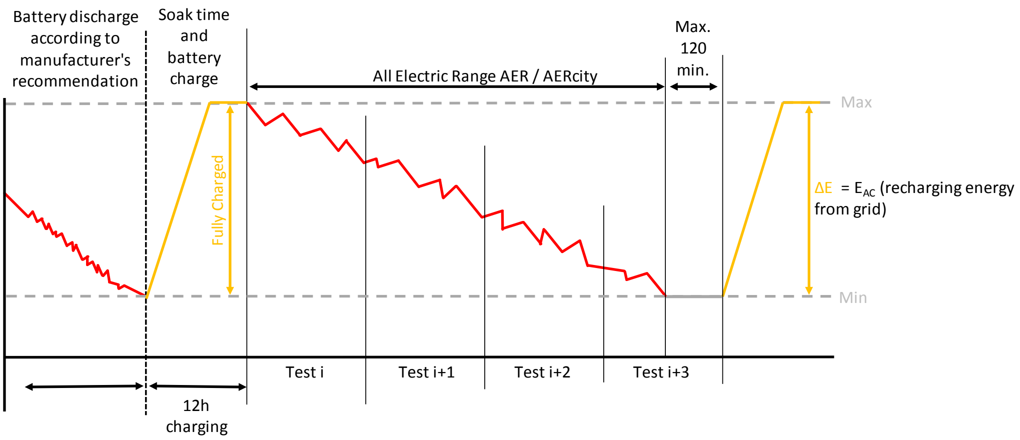
PEV, electric range and electric energy consumption test



Sub-Annex 8 -Appendix 2

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REESS charge balance (RCB) correction

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1. This Appendix describes the test procedure for RCB compensation of CO_2 and fuel consumption measurement results when testing NOVC-HEV and OVC-HEV vehicles.

1.1. Separate CO_2 emission and fuel consumption correction coefficients shall be calculated separately for each phase of the WLTC and corrected to zero over each WLTC phase.

2. The fuel consumption correction coefficients (K_{fuel}) shall be defined as follows and might be supplied by the manufacturer:

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2.1. The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with $E_{REESSi} \leq 0$ and at least one with $E_{REESSi} > 0$ over the complete test cycle.

If the latter condition cannot be realised on the driving cycle used in this test, the approval authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

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2.1.1. The fuel consumption correction coefficients (K_{fuel}) for the individual phases as well as for the complete test cycle are defined as:

$$K_{fuel} = \frac{(n \times \sum E_{REESS} \times FC_i - \sum E_{REESSi} \times \sum FC_i)}{n \times \sum E_{REESSi}^2 - (\sum E_{REESSi})^2} \qquad (1)$$

where:

K_{fuel} are the fuel consumption correction coefficients, l/100 km/Wh/km;

FC_i are the fuel consumptions measured during the i^{th} test, l/100 km;

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E_{REESSi} are the electricity balances measured during the i^{th} test, Wh/km;

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n is the number of measurements.

The fuel consumption correction coefficient shall be rounded to four significant figures. The statistical significance of the fuel consumption correction coefficient is to be evaluated by the approval authority.

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2.2. The fuel consumption correction coefficient shall be determined for the fuel consumption values measured over WLTC. This coefficient can be applied for each individual WLTC phase correction.

2.2.1. Without prejudice to the requirements of paragraph 2.1. of this Appendix, at the manufacturer's request, separate fuel consumption correction coefficients for each individual WLTC phase may be developed.

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2.3. Fuel consumption at zero REESS energy balance (FC_0)

2.3.1. The fuel consumption FC_0 at $\Delta E_{REESS} = 0$ shall be determined by the following equation:

$$FC_0 = FC - K_{fuel} \times \Delta E_{REESS} \quad (2)$$

where:

FC_0 is the fuel consumption at ΔE_{REESS} = 0, l/100 km;

FC is the fuel consumption measured during the test, l/100 km;

ΔE_{REESS} is the electricity balance measured during test, Wh/km.

2.3.2. Fuel consumption at zero REESS energy balance shall be calculated separately for each phase of the WLTC and corrected to zero over each WLTC phase.

2.3.3. Fuel consumption at zero REESS energy balance shall also be calculated for the complete WLTC and corrected to zero.

3. CO_2 emission correction coefficient (K_{CO_2}) shall be defined as follows and may be supplied by the manufacturer

3.1. The CO_2 emission correction coefficient (K_{CO_2}) shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with $E_{REESSi} \leq 0$ and at least one with $E_{REESSi} > 0$ over the complete test cycle.

If the latter condition cannot be realised on the driving cycle used in this test, the approval authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

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3.1.1. The CO_2 emission correction coefficient (K_{CO_2}) is defined as:

$$K_{CO_2} = \frac{(n \times \sum E_{REESS} \times M_i - \sum E_{REESSi} \times \sum M_i)}{n \times \sum E_{REESSi}^2 - (\sum E_{REESSi})^2} \quad (3)$$

where:

K_{CO_2} are the CO_2 emissions correction coefficient, g/km/Wh/km;

M_i are the CO_2 emissions measured during the ith test, g/km;

E_{REESSi} is the electricity balance during the ith test, Wh/km;

n is the number of measurements.

3.1.2. The CO_2 emission correction coefficient shall be rounded to four significant figures. The statistical significance of the CO_2 emission correction coefficient is to be judged by the approval authority.

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3.1.3. The CO_2 emission correction coefficient shall be determined for the CO_2 emission values measured over the WLTC. This coefficient may be applied for each individual WLTC phase correction.

3.1.3.1 Without prejudice to the requirements of paragraph 2.1. of this Appendix, at the manufacturer's request, separate CO_2 emission correction coefficients for each individual WLTC phase may be developed.

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3.1.4. CO_2 emissions at zero REESS energy balance shall be also calculated for complete WLTC and corrected to zero.

3.2. CO_2 emission at zero REESS energy balance (M_0)

3.2.1. The CO_2 emission M_0 at $\Delta E_{REESS} = 0$ shall be determined by the following equation:

$$M_0 = M - K_{CO_2} \times \Delta E_{REESSi} \qquad (4)$$

where:

M_0 are the CO_2 emissions at zero REESS energy balance, g/km;

K_{CO_2} are the CO_2 emissions correction coefficient, g/km/Wh/km;

ΔE_{REESSi} is the electricity balance measured during test, Wh/km.

Sub-Annex 8 -Appendix 3

Measuring the electricity balance of NOVC-HEV and OVC-HEV batteries

1. Introduction

1.1. This Appendix defines the method and required instrumentation to measure the electricity balance of OVC-HEVs and NOVC-HEVs.

2. Measurement equipment and instrumentation

2.1. During the tests described in paragraph 3. of this Sub-Annex, the REESS current can be measured using a current transducer of the clamp-on or closed type. The current transducer (i.e. a current sensor without data acquisition equipment) shall have a minimum accuracy specified in paragraph 2.1.1. of Appendix 2 to Sub-Annex 6.

2.1.1. Alternatively to paragraph 2.1 above, the RCB determination method described in paragraph 2.2. of Appendix 2 to Sub-Annex 6 shall be applicable for all vehicle REESSs.

2.1.2. The current transducer shall be fitted on one of the cables directly connected to the REESS. In order to easily measure REESS 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 approval authority by providing the means to connect a current transducer to the wires connected to the REESS in the above described manner.

2.1.3. 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 RCB, expressed in ampere-hours (Ah).

2.2. A list of the instrumentation (manufacturer, model no., serial no.) used by the manufacturer to determine:

(a) When the minimum state of charge of the REESS has been reached during the test procedure defined in paragraph 3. of this Sub-Annex;

(b) The correction factors K_{fuel} and K_{CO_2} (as defined in Appendix 2 to this Sub-Annex);

(c) The last calibration dates of the instruments (where applicable) shall be provided to the approval authority.

3. Measurement procedure

3.1. Measurement of the REESS 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. The RCB values of each phase shall be included in the test report.

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Sub-Annex 8 -Appendix 4

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Preconditioning of PEVs and OVC-HEVs

1. This Appendix describes the test procedure for REESS and combustion engine preconditioning in preparation for:

   (a) Electric range, charge-depleting and charge-sustaining measurements when testing OVC-HEV; and

   (b) Electric range measurements as well as electric energy consumption measurements when testing PEV vehicles.

2. OVC-HEV combustion engine and REESS preconditioning

   When testing in charge-sustaining condition is followed by testing in charge-depleting condition, the charge-sustaining condition test and the charge-depleting test may be driven independently of one another. In that case, the vehicle shall be prepared as prescribed in paragraph 2.1.1. below before the charge-depleting test or the charge-sustaining test starts.

2.1. OVC-HEV combustion engine and REESS preconditioning when the test procedure starts with a charge-sustaining test

2.1.1. For preconditioning of the combustion engine, the OVC-HEV shall be driven over at least one WLTC. The manufacturer shall guarantee that the vehicle operates in a charge-sustaining condition.

2.1.2. When testing an OVC-HEV with driver-selectable operation mode, the preconditioning cycles shall be performed in the same operation condition as the charge-sustaining test as described in paragraph 3.2.5. of this Sub-Annex.

2.1.3. During the preconditioning cycle in paragraph 2.1.2. above, the charging balance of the traction REESS shall be recorded. The preconditioning shall be stopped at the end of the cycle when the break-off criterion is fulfilled according to paragraph 3.2.4.5. of this Sub-Annex.

2.1.4. Alternatively, at the request of the manufacturer, the state of charge of the REESS for the charge-sustaining test can be set according to the manufacturer's recommendation in order to achieve a charge balance neutral charge-sustaining test.

   In such a case, an additional ICE preconditioning procedure, such as that applicable to conventional vehicles as described in paragraph 1.2.6. of Sub-Annex 6, may be applied.

2.1.5. Soaking of the vehicle shall be performed according to paragraph 1.2.7. of Sub-Annex 6. Forced cooling down shall not be applied to vehicles preconditioned for the charge-depleting test.

2.2. OVC-HEV combustion engine and REESS preconditioning when the test procedure starts with a charge-depleting test

2.2.1. For preconditioning of the combustion engine, the OVC-HEV shall be driven over at least one WLTC. The manufacturer shall guarantee that the vehicle operates in a charge-sustaining condition.

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For calculation purposes?
AdminWG 290414 – confirmed that it is for calculation purposes only.

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2.2.2. When testing an OVC-HEV with driver-selectable operation mode, the preconditioning cycles shall be performed in the same operation condition as the charge-sustaining test as described in paragraph 3.2.5. of this Sub-Annex.

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2.2.3. Soaking of the vehicle shall be performed according to paragraph 1.2.7. of Sub-Annex 6. Forced cooling down shall not be applied to vehicles preconditioned for the test.

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2.2.4. During soak, the electrical energy storage device shall be charged, using the normal charging procedure as defined in paragraph 2.2.5. below.

2.2.5. Application of a normal charge

2.2.5.1. The electrical energy 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 charging pattern prescribed for normal charging;

(c) In an ambient temperature as specified in paragraph 1.2.2.2.2. of Sub-Annex 6. This procedure excludes all types of special charges that could be automatically or manually initiated, e.g. equalization charges or servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred.

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2.2.5.2. End of charge criterion

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The end of charge criterion is reached when a fully charged REESS is detected by the on-board or external instruments.

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3. PEV REESS conditioning

3.1. Initial charging of the REESS

Charging the REESS consists of discharging the REESS and applying a normal charge.

3.1.1. Discharging the REESS

Discharge test procedure shall be performed according to the manufacturer's recommendation. The manufacturer will guarantee that the REESS is as fully depleted as is possible by the discharge test procedure.

3.1.2. Application of a normal charge

The REESS shall be charged:

(a) With the on-board charger if fitted; or

(b) With an external charger recommended by the manufacturer using the charging pattern prescribed for normal charging;

(c) In an ambient temperature as specified in paragraph 1.2.2.2.2. of Sub-Annex 6. This procedure excludes all types of special charges that could be automatically or manually initiated, e.g. equalization charges or servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred.

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3.1.3. End of charge criterion

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The end of charge criterion is reached when a fully charged REESS is detected by the on-board or external instruments.

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Sub-Annex 8 -Appendix 5

Utility factor (UF) for OVC-HEVs

1. Utility Factors (UFs) are ratios based on driving statistics and the ranges achieved in charge-depleting mode and charge-sustaining modes for OVC-HEVs and are used for weighting emissions, CO_2 emissions and fuel consumptions.

2. For the calculation of each phase specific utility factor (UF), the following equation shall be applied:

$$UF_i(d_i) = 1 - \exp\left(-\left(\sum_{j=1}^{k} C_j * \left(\frac{d_i}{d_n}\right)^j\right)\right) - \sum_{l=1}^{i-1} UF_l \qquad (1)$$

UF_i - Utility factor for phase i.

d_i - Distance driven to the end of phase i in km.

C_j - j^{th} coefficient (see Table A8.App5/1).

d_n - Normalized distance (see Table A8.App5/1).

k - Amount of terms and coefficients in the exponent (see Table A8.App5/1).

i - Number of considered phase.

j - Number of considered term/coefficient.

$\sum_{l=1}^{i-1} UF_l$ - Sum of calculated utility factors up to phase (i-1).

The curve that is based on the following parameters in Table A8.App5/1 is valid from 0 km to the normalized distance d_n. For distances higher than d_n, a Utility Factor of 1 shall be applied.

Table A8.App5/1
Parameter to be used in Equation y

C_1	27.27
C_2	-35.21
C_3	-145.63
C_4	858.01
C_5	-1867.42
C_6	2089.72
C_7	-1192.92
C_8	276.29
d_n [km]	800
k	8

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Comment [RCG212]: From GTR 11.05.14

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Comment [RCG213]: Some additional text will be added to provide the rationale behind the development of the formula, such as the database that was used to generate the curve.

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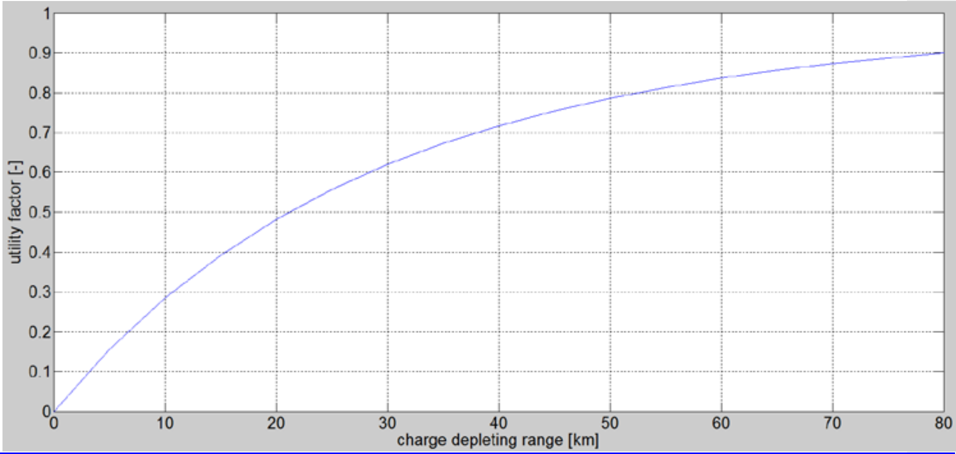
The curve shown below in Figure A8/App5/1 is provided for illustrative purposes only. It does not form part of the regulatory text.

Figure A8.App5/1

Utility Factor curve based on equation parameter of Table A8.App5/1



Example

The fractional Utility Factors for Class 3b vehicles with $v_{max} \geq 120$ km/h are shown in Table A8.App5/2 below.

Table A8.App5/2

Utility Factors for Class 3b vehicles with $v_{max} \geq 120$ km/h

WLTC	phase	phase i	distance [km]	cumulated distance d_i [km]	fractional UF_i [-]	cumulated UF [-]
1	Low	1	3.095	3.095	0.100	0.100
	Mid	2	4.756	7.850	0.132	0.232
	High	3	7.162	15.012	0.160	0.393
	Extra high	4	8.254	23.266	0.140	0.532
2	Low	5	3.095	26.361	0.043	0.575
	Mid	6	4.756	31.117	0.057	0.632
	High	7	7.162	38.278	0.070	0.702
	Extra high	8	8.254	46.533	0.062	0.765
3	Low	9	3.095	49.627	0.019	0.784
	Mid	10	4.756	54.383	0.026	0.810
	High	11	7.162	61.545	0.032	0.843
	Extra high	12	8.254	69.799	0.029	0.872
4	Low	13	3.095	72.893	0.009	0.881
	Mid	14	4.756	77.649	0.013	0.894
	High	15	7.162	84.811	0.016	0.910
	Extra high	16	8.254	93.065	0.015	0.925

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[RESERVED:

Sub-Annex 8 - Appendix 6

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Determining the range of PEVs on a per-phase basis]

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Sub-Annex 9

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Determination of system equivalence]

Sub-Annex 10

European normalisation procedures

1. Introduction

Submitted by the European Commission

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Agenda item 3a

Sub-Annex 10 – Appendix 1

Supplemental Test for determination of CO_2 emissions under representative regional conditions

1. Introduction

This Appendix describes xxx

2. Definitions:

2.1. "*Active heat storage device*" means a technology that stores heat within any device of a vehicle and releases the heat to a power train component over a defined time period at engine start. It is characterized by the stored enthalpy in the system and the time for heat release to the power train components.

2.2. T_{reg} is the regional representative temperature for the supplemental test, Kelvin (K)

2.3. t_{park} is the regional representative mean parking time for the supplemental test, seconds (s)

3 The Type 1 test specified in Annex 6 shall be carried out with the exception of the following points:

3.1. Ambient conditions for supplemental test

3.1.1.

The regional representative temperature (T_{reg}) at which the vehicle should be soaked and tested shall be 287 K (14°C).

3.1.2.

The minimum soaking time (t_{park}) shall be 9 hours.

3.2. Test cell and soak area

3.2.1. Test cell

3.2.1.1. The test cell shall have a temperature set point equal to the regional representative temperature T_{reg}. The tolerance of the actual temperature value shall be within ± 3 K at the beginning of the test and within ±5 K during the test.

3.2.1.2 . The specific humidity (H) of either the air in the test cell or the intake air of the engine shall be such that:

$3.0 \leq H \leq 7.0$ (g H_2O/kg dry air)

3.2.1.3. Humidity shall be measured continuously at a minimum of 1 Hz.

3.2.1.4. The air temperature and humidity shall be measured at the outlet of the vehicle cooling fan at a rate of 1 Hz.

3.2.2. Soak area

3.2.2.1. The soak area shall have a temperature set point equal to T_{reg} and the tolerance of the actual value shall be within ±3 K.

3.3. Test vehicle

Comment [RCG214]: Text prepared by ATCT working group. Based on original text drafted by Audi/BMW November 2013

Updated 22nd April following audio/web
+
25th April following second audio/web
+
290414 AdminWG
+
140514 – third audio web meeting
+
020614 – fourth audio web meeting

Comment [RCG215]: TRL to provide some introductory text here.

Deleted: The vehicle shall be soaked and tested at the regional representative temperature T_{reg} which shall be 287 K (14 °C).

Deleted: The minimum soaking time is defined by the regional representative mean parking time t_{park}. This shall be 9 h with a tolerance of + 0 to 2 h.

Comment [RCG216]: **New range proposed by M.Bergmann** 3 – 7 g H2O/kg dry air (~30 to 69 % rel. Hum.). This range is equivalent to the range of 5.5 – 12.2 for the Type 1 test at 23 deg C.

Needs to be approved.

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The vehicle to be tested shall be representative for the family for which the supplemental data are determined (as described in paragraph 3.9. of this Appendix).

From the Supplemental Test Vehicle Family, the CO_2 Vehicle Family with the lowest engine capacity shall be selected (see paragraph 3.9.2.1. of this Appendix), and the test vehicle shall be in the 'vehicle H' configuration of this family.

Where the vehicle has an active heat storage device, then the vehicle with the lowest enthalpy and the slowest heat release for the active heat storage device shall be selected.

The test vehicle shall meet the requirements detailed in paragraph 1.2.3. of Sub-Annex 6.

3.4. Settings

3.4.1. Road load and dynamometer settings shall be as specified in Sub-Annex 4.

3.5. Preconditioning

3.5.1. The vehicle shall be preconditioned as described in paragraph 1.2.6. of Sub-Annex 6. At the request of the manufacturer preconditioning may be undertaken at 287 K (14 °C).

3.6. Soak

3.6.1. After this preconditioning, and before testing, vehicles shall be kept in a room with the ambient conditions described in paragraph 3.2.2. of this Appendix.

3.6.2. Soaking shall be carried out as follows:

3.6.2.1. The transfer from the preconditioning to the soak area shall be undertaken as quickly as possible, with a maximum delay of 10 minutes. The vehicle shall then be kept in the soak area at the conditions defined in paragraph 3.2.2. of this Appendix for a minimum of the defined time t_{park} but no longer than t_{park} + 2 hours. The soak shall be performed without using a cooling fan and with all body parts positioned as intended under normal parking operation.

3.7. Emission Test

3.7.1. Emissions test: The test vehicle shall be pushed as quickly as possible, and with a maximum delay of 10 minutes, onto a dynamometer and operated through the cycles as specified in Sub-Annex 1 for that class of vehicle.

3.7.2. The procedures for undertaking the emissions test as specified in Sub-Annex 6 shall be followed, but with the ambient conditions for the test cell being those as described in paragraph 3.2.1. of this Appendix.

3.8. Calculation and Documentation

3.8.1. Supplemental test data and results have to be documented following the prescriptions of Sub-Annex 7.

The CO_2 correction value shall be calculated. The CO_2 base test is the Type 1 test with the vehicle H.

The family correction factor (FCF) shall be calculated as follows:

FCF = (CO_2 Type-X @ T_{reg}) / (CO_2 Type 1 @ 296 K)

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Comment [RCG217]: Supplemental test is called "Type-X" test here.
Need to decide what to call the test. "Type 1b" is a possibility.

3.8.2. The individual CO_2 value for each vehicle (as calculated using the procedure in paragraph 3.2.3. of Sub-Annex 7) in the Supplemental Test vehicle Family (as defined in paragraph 3.9. of this Appendix) shall be calculated from the Type 1 CO_2 value and the FCF using the following formula:

$CO_2\_ind = CO_2\_ind @ 296 K \times FCF$

3.8.3. [Add details of the FCF documentation requirements]

3.9. Definition of Supplemental Test Family

3.9.1. Unless vehicles are identical with respect to all the following characteristics, they shall not be considered to be part of the same supplemental test family:

(a) Powertrain architecture (i.e. internal combustion, hybrid, or electric);

(b) Combustion process (i.e. two stroke or four stroke);

(c) Number and arrangement of cylinders;

(d) Method of engine combustion (i.e. indirect or direct injection);

(e) Type of cooling system (i.e. air, water, or oil);

(f) Method of aspiration (i.e. naturally aspirated, or charged);

(g) Fuel for which the engine is designed (i.e. petrol, diesel, NG, LPG, etc.);

(h) Whether or not an active heat storage device is installed (see paragraph 3.9.2.2. if such a device/technology is installed);

(i) Catalytic converter (i.e. three-way catalyst, lean NOx trap, SCR, lean NOx catalyst or other(s));

(j) Whether or not a particulate trap is installed; and

(k) Exhaust gas recirculation (with or without, cooled or non-cooled).

In addition the vehicles shall be similar with respect to the following characteristics:

(l) The vehicles shall have a variation in engine cylinder capacity of no more than 30% of the vehicle with the lowest capacity; and

(m) Engine compartment insulation shall be of a similar type regarding material, amount and location of the insulation. Manufacturers shall provide evidence (e.g. by CAD drawings) to the approval authority that the volume and weight of the installed insulation material is within a tolerance of [10]% to the Supplemental Test measured reference vehicle.

3.9.2. **Provision for cool down and heat storage characteristics**

3.9.2.1. For the test vehicle and all vehicles H of the CO_2 vehicle families within the supplemental test family (STF), the end temperature of the engine coolant after driving the respective Type 1 test @ 296 K and after soaking @ 296 K for the representative regional soak time of 9 hours + 0 to 2 shall be measured.

The cool down measurement shall be undertaken as soon as possible after the end of the Type 1 test, with a maximum delay of 10 minutes.

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Comment [RCG218]: Deleted based on input from S.Dubuc

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Comment [RCG219]: Need to confirm the tolerance once a better understanding of the weight and volume has been gained.

Action from meeting 140514 – A.Eder and L.Bigi to look at the information available.

020614 update: Some information from BMW has been looked at but further information is to be obtained before a final proposal is made.

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Within the STF the average soak area temperature of the last 3 hours of the soak process has to be subtracted from the measured end temperature. Unless the resulting temperature difference is within the range [-2K to +4K] to the reference vehicle temperature this CO_2 vehicle family shall not be considered to be a member of the same STF.

For all vehicles within a STF the coolant shall be measured at the same location in the cooling system.

3.9.2.2. If active heat storage devices are installed, unless vehicles meet the following requirements they shall not be considered to be part of the same STF:

(a) the heat capacity, defined by the enthalpy stored in the system, is within a range of % 0 to10% above the enthalpy of the test vehicle; and

(b) the time for heat release at engine start within a family is within a range of 0 to10% above the time for the heat release of the test vehicle.

3.10. For OVC-HEVs, the Charge Sustaining CO_2 value shall be corrected according to the requirements of this Appendix. No correction is required for the CO_2 value from the Charge Depleting Test or for the Electric Range in the Charge Depleting test.

Comment [RCG220]: Following analysis by A.Eder and discussion at the ATCT working group on 020614 a range of -2K to +4K has been proposed.

To be approved.

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