Submitted by the IWG on WLTP

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26.05.2015 Benchmark ECE-TRANS-WP29-2014-27 and Corr 1
WLTP-11-04e-clean GTR version 26.05.2015

Comments to this clean version

- All confirmed items from the 26.05.2015 version of the GTR have been integrated in the clean version and the tracking changes have been deleted
- Major items not yet confirmed are:
  - Use of the term PM. JRC has made comments since the April drafting subgroup meeting.
  - Definitions. Many items are labelled "Confirmation" but have been reopened for discussion.
  - Wind tunnel method. Final details to be worked out.
  - Additional pollutants (NH3, ethanol, formaldehyde). Text expected.
  - Annex 8
- A number of minor items remain, many of which will be discussed by the drafting subgroup
- This version is a working version. Formatting and editorial corrections such as proper tabs, double spaces and missing spaces are still present.

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Consideration and vote by AC.3 of draft UN Global Technical Regulations and/or draft amendments to established UN Global Technical Regulations
Proposal for a global technical regulation on the Worldwide harmonized Light vehicles Test Procedure

Proposal for a new global technical regulation on the Worldwide harmonized Light vehicles Test Procedure (WLTP)

Submitted by the Working Party on Pollution and Energy*

The text reproduced below was adopted by the Working Party on Pollution and Energy (GRPE) at its sixty-seventh session (ECE/TRANS/WP.29/GRPE/67, para. 6.). Based on ECE/TRANS/WP.29/GRPE/2013/13, as amended by GRPE-67-04-Rev.1, it is submitted to the World Forum for Harmonization of Vehicle Regulations (WP.29) and to the Administrative Committee AC.3 for consideration.

* In accordance with the programme of work of the Inland Transport Committee for 2012–2016 (ECE/TRANS/224, para. 94 and ECE/TRANS/2012/12, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

Draft global technical regulation on Worldwide harmonized Light vehicle Test Procedures (WLTP)

I. Statement of technical rationale and justification

A. Introduction

1. The compliance with emission standards is a central issue of vehicle certification worldwide. Emissions comprise criteria pollutants having a direct (mainly local) negative impact on health and environment, as well as pollutants having a negative environmental impact on a global scale. Regulatory emission standards typically are complex documents, describing measurement procedures under a variety of well-defined conditions, setting limit values for emissions, but also defining other elements such as the durability and on-board monitoring of emission control devices.

2. Most manufacturers produce vehicles for a global clientele or at least for several regions. Albeit vehicles are not identical worldwide since vehicle types and models tend to cater to local tastes and living conditions, the compliance with different emission standards in each region creates high burdens from an administrative and vehicle design point of view. Vehicle manufacturers, therefore, have a strong interest in harmonizing vehicle emission test procedures and performance requirements as much as possible on a global scale. Regulators also have an interest in global harmonization since it offers more efficient development and adaptation to technical progress, potential collaboration at market surveillance and facilitates the exchange of information between authorities.

3. As a consequence stakeholders launched the work for this global technical regulation (gtr) on Worldwide harmonized Light vehicle Test Procedures (WLTP) that aims at harmonizing emission-related test procedures for light duty vehicles to the extent this is possible. Vehicle test procedures need to represent real driving conditions as much as possible to make the performance of vehicles at certification and in real life comparable. Unfortunately, this aspect puts some limitations on the level of harmonization to be achieved, since for instance, ambient temperatures vary widely on a global scale. In addition, due to the different levels of development, different population densities and the costs associated with emission control technology, the regulatory stringency of legislation is expected to be different from region to region for the foreseeable future. The setting of emission limit values, therefore, is not part of this gtr for the time being.

4. The purpose of a gtr is its implementation into regional legislation by as many Contracting Parties as possible. However, the scope of regional legislations in terms of vehicle categories concerned depends on regional conditions and cannot be predicted for the time being. On the other hand, according to the rules of the 1998 UNECE agreement, Contracting Parties implementing a gtr shall include all equipment falling into the formal gtr scope. Care shall be taken, so that an unduly large formal scope of the gtr does not prevent its regional implementation. Therefore the formal scope of this gtr is kept to the core of light duty vehicles. However, this limitation of the formal gtr scope does not indicate that it could not be applied to a larger group of vehicle categories by regional legislation. In fact, Contracting Parties are encouraged to extend the scope of regional implementations of this gtr if this is technically, economically and administratively appropriate.

5. This first version of the WLTP gtr, in particular, does not contain any specific test requirements for dual fuel vehicles and hybrid vehicles not based on a combination of an

internal combustion engine and an electric machine. For example, specific requirements for hybrids using fuel cells or compressed gases as energy storage are not covered. Thus these vehicles are not included in the scope of the WLTP gtr. Contracting Parties may however apply the WLTP gtr provisions to such vehicles to the extent possible and complement them by additional provisions, e.g. emission testing with different fuel grades and types, in regional legislation.

Comment [SMD1]: EXPERT PROPOSAL: March 2015 drafting meeting
Japan proposes deleting the whole sentence or delete "fuel cells".

B. Procedural background and future development of the WLTP

6. In its November 2007 session, WP.29 decided to set up an informal WLTP group under GRPE to prepare a road map for the development of the WLTP. After various meetings and intense discussions, WLTP presented in June 2009 a first road map consisting of 3 phases, which was subsequently revised a number of times and contains the following main tasks:

(a) Phase 1 (2009 – 2014): development of the worldwide harmonized light duty driving cycle and associated test procedure for the common measurement of criteria compounds, CO_2, fuel and energy consumption.

(b) Phase 2 (2014 – 2018): low temperature/high altitude test procedure, durability, in-service conformity, technical requirements for on-board diagnostics (OBD), mobile air-conditioning (MAC) system energy efficiency, off-cycle/real driving emissions.

(c) Phase 3 (2018 - …): emission limit values and OBD threshold limits, definition of reference fuels, comparison with regional requirements.

7. It should be noted that since the beginning of the WLTP process, the European Union had a strong political objective set by its own legislation (Regulations (EC) 443/2009 and 510/2011) to implement a new and more realistic test cycle by 2014, which was a major political driving factor for setting the time frame of phase 1.

8. For the work of phase 1 the following working groups and subgroups were established:

(a) Development of Harmonised Cycle (DHC): construction of a new Worldwide Light-duty Test Cycle (WLTC), i.e. the driving curve of the WLTP, based on ~~the~~ statistical analysis of real driving data.

The DHC group started working in September 2009, launched the collection of driving data in 2010 and proposed a first version of the driving cycle by mid-2011, which was revised a number of times to take into consideration technical issues such as driveability and better representativeness of driving conditions after a first validation.

(b) Development of Test Procedures (DTP): development of test procedures with the following specific expert groups,

(i) PM-PN: Particle mass (PM) and particle number (PN) measurements.

(ii) AP: Additional Pollutant measurements, i.e. measurement procedures for exhaust substances which are not yet regulated ~~yet~~ as compounds but may be regulated in the near future, such as NO_2, ethanol, aldehydes and ammonia.

(iii) LabProcICE: test conditions and measurement procedures of existing regulated compounds for vehicles equipped with internal combustion engines (other than PM and PN).

Comment [SMD2]: OPEN POINT: 22.04.2015: Stockholm IWG 10. The meaning of PM is still being discussed.

(iv) EV-HEV: specific test conditions and measurement procedures for electric and hybrid-electric vehicles.

(v) Reference fuels: definition of reference fuels.

The DTP group started working in April 2010.

9. This first version of the gtr will only contain results of phase 1. During the work of the DTP group it became clear that a number of issues, in particular but not only in relation to electric and hybrid-electric vehicles, could not be resolved in time for an adoption of the first version of the WLTP gtr by WP.29 in March 2014. Therefore it was agreed that these elements would be further developed by the existing expert groups and should be adopted as a "phase 1b" amendment to the WLTP gtr within an appropriate time frame. Without claiming completeness "phase 1b" should address the following work items:

(a) LabProcICE:

(i) Normalization methods, speed trace index;

(ii) Energy economy rating and absolute speed change rating for speed trace violations;

(iii) Wind tunnel as alternative method for road load determination;

(iv) Supplemental test with representative regional temperature and soak period.

(b) EV-HEV:

(i) Calculation method of each phase range for Pure Electric Vehicles (PEVs);

(ii) Shortened test procedure for PEV range test;

(iii) Combined CO_2 (fuel consumption) of each phase for Off-Vehicle Charging Hybrid Electric Vehicles (OVC-HEVs);

(iv) Hybrid Electric Vehicle (HEV)/PEV power and maximum speed;

(v) Combined test approach for OVC-HEVs and PEVs;

(vi) Fuel cell vehicles;

(vii) Utility factors;

(viii) Preconditioning;

(ix) Predominant mode.

(c) APM:

measurement method for ammonia, ethanol and aldehydes.

(d) DHC:

(i) Speed violation criteria;

(ii) Further downscaling in Wide Open Throttle (WOT) operation;

(iii) Sailing and gear shifting.

C. Background on driving cycles and test procedures

10. The development of the worldwide harmonized light duty vehicle driving cycle was based on experience gained from work on the World-wide Heavy-Duty Certification

procedure (WHDC), World-wide Motorcycle Test Cycle (WMTC) and other national cycles.

11. The WLTC is a transient cycle by design. For constructing the WLTC, driving data from all participating Contracting Parties were collected and weighted according to the relative contribution of regions to the globally driven mileage and data collected for WLTP purpose.

12. The resulting driving data were subsequently cut into idling periods and "short trips" (i.e. driving events between two idling periods). By randomised combinations of these segments, a large number of "draft cycles" were generated. From the latter "draft cycle" family, the cycle best fitting certain dynamic properties of the original WLTP database was selected as a first "raw WLTC". In the subsequent work the "raw WLTC" was further processed, in particular with respect to its driveability and better representativeness, to obtain the final WLTC.

13. The driveability of the WLTC was assessed extensively during the development process and is supported by three distinct validation phases. Specific cycle versions for certain vehicles with limited driving capabilities due to a low power/mass ratio or limited maximum vehicle speed have been introduced. In addition, the speed trace to be followed by a test vehicle will be downscaled according to a mathematically prescribed method if the vehicle would have to encounter an unduly high proportion of "full throttle" driving in order to follow the original speed trace. Gear shift points are determined according to a mathematical procedure that is based on the characteristics of individual vehicles, which also enhances the driveability of the WLTC.

14. For the development of the test procedures, the DTP subgroup took into account existing emissions and energy consumption legislation, in particular those of the 1958 and 1998 Agreements, those of Japan and the United States Environmental Protection Agency (US EPA) Standard Part 1066. These test procedures were critically reviewed, compared to each other, updated to technical progress and complemented by new elements where necessary.

D. Technical feasibility, anticipated costs and benefits

15. In designing and validating the WLTP, strong emphasis has been put on its practicability, which is ensured by a number of measures explained above.

16. While in general the WLTP has been defined on the basis of the best technology available at the moment of its drafting, the practical facilitation of the WLTP procedures on a global scale has been kept in mind as well. The latter had some impact e.g. on the definition of set values and tolerances for several test parameters, such as the test temperature or deviations from the speed trace. Also, facilities without the most recent technical equipment should be able to perform WLTP certifications, leading to higher tolerances than those which would have been required just by best performing facilities.

17. The replacement of a regional test cycle by the WLTP initially will bear some costs for vehicle manufacturers, technical services and authorities, at least considered on a local scale, since some test equipment and procedures have to be upgraded. However, these costs should be limited since such upgrades are done regularly as adaptations to the technical progress. Related costs would have to be quantified on a regional level since they largely depend on the local conditions.

18. As pointed out in the technical rationale and justification, the principle of a globally harmonized light duty vehicle test procedure offers potential cost reductions for vehicle manufacturers. The design of vehicles can be better unified on a global scale and

administrative procedures may be simplified. The monetary quantification of these benefits depends largely on the extent and timing of implementations of the WLTP in regional legislation.

19. The WLTP provides a higher representation of real driving conditions when compared to the previous regional driving cycles. Therefore, benefits are expected from the resulting consumer information about fuel and energy consumption. In addition, a more representative WLTP will set proper incentives for implementing those CO_2 saving vehicle technologies that are also the most effective in real driving. The effectiveness of technology costs relative to the real driving CO_2 savings will, therefore, be improved with respect to existing less representative driving cycles.

II. Text of the global technical regulation

1. 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. 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

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.

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 shall 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 gtr, 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.

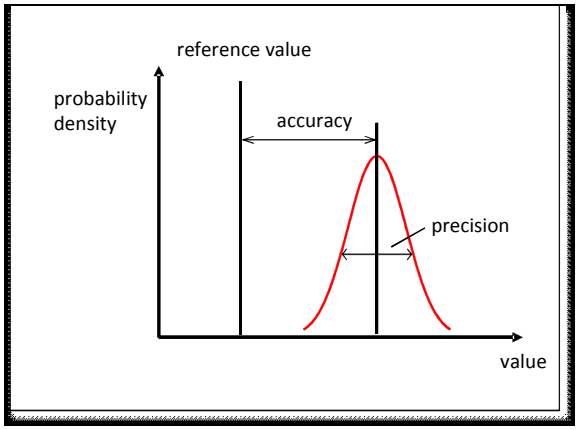
3.1.12. "*Span*" means to adjust an instrument so that it gives a proper response to a calibration standard that represents between 75percent and 100percent of the maximum value in the instrument range or expected range of use.

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. "*Anemometer 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.

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 90percent of its or their capacity/capacities, including the

mass of the driver, 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..

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 the technically permissible maximum laden mass minus the mass in running order, 25 kg and the mass of the optional equipment as defined in paragraph 3.2.8...

3.2.8. "*Mass of 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.xx. "*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.

Comment [SMD3]: EXPERT PROPOSAL: 08.02.2015

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, unless otherwise specified by regulations;

(b) Atmospheric temperature: T_0 = 293 K, unless otherwise specified by regulations;

(c) Dry air density: ρ_0 = 1.189 kg/m^3, unless otherwise specified by regulations;

(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.

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.

3.2.16. "*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.

3.2.17. "*Standard equipment*" means the basic configuration of a vehicle which is equipped with all the features that are required under the regulatory acts of the Contracting Party including all features that are 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.

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

3.2.b. "*Technically permissible maximum laden mass*" 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 fitted optional equipment 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.d. "*Test mass of the vehicle*" means the sum of the mass of the vehicle in running order and its actually fitted optional equipment plus 25 kg and the mass representative of the vehicle load;

3.2.e. "*Mass representative of the vehicle load*" means 15 per cent for category 1 vehicles and 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) means in the case of an off-vehicle charging hybrid electric vehicle (OVC-HEV) the total distance travelled from the beginning of the charge-depleting test to the point in time during the test when the combustion engine starts to consume fuel.

3.3.2. "*All-electric range*" (AER) means in the case of a pure electric vehicle (PEV) the total distance travelled from the beginning of the charge-depleting test 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 decreases on average while the vehicle is driven until transition to charge-sustaining operation.

Comment [SMD4]: CONFIRMATION: CONFIRMATION: April 2015 drafting meeting, Stockholm.

Comment [SMD5]:

Comment [SMD6]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD7]: CONFIRMATION: March 2015 drafting meeting.

Comment [SMD8]:

Comment [SMD9]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD10]:

Comment [SMD11]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD12]: EXPERT PROPOSAL: 12.09.2014: Deadline for expert comments: 31.10.2014.

Comment [SMD13]: Day XXX: proposed by rob cuelenaere

Comment [SMD14]:

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.

3.3.10. "*Energy converter*" means the part of the powertrain where the form of energy input is different from the form of energy output

3.3.11. "*Energy storage system*" means the part of the powertrain on board a vehicle that can store energy and release it in the same form as it was input.

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.

3.3.14. "*Hybrid electric vehicle*" (HEV) means a hybrid vehicle where one of the energy converters is an electric machine.

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.

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

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

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.

3.4. 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. "*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.

3.5.3. "*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.

Comment [SMD15]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD16]: CONFIRMATION: March 2015 drafting meeting, Brussels. Deletion approved.

Comment [SMD17]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD18]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD19]: OPEN POINT: 18.05.2014: This term is not used in the GTR. Request to all experts that the definition be deleted.
The term "Highest electric energy consumption mode" is however used in the GTR.

Comment [SMD20]: OPEN POINT: 12.09.2014: Deadline for expert comments: 31.10.2014.

Comment [SMD21]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD22]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD23]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD24]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD25]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD26]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, ad... [1]

Comment [SMD27]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD28]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, ad... [2]

Comment [SMD29]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD30]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, ad... [3]

Comment [SMD31]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD32]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, ad... [4]

Comment [SMD33]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD34]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, ad... [5]

Comment [SMD35]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD36]: GTR CORRECTION: 03.11.2014: DC proposes to move the definiti... [6]

Comment [SMD37]: CONFIRMATION: 17.12.2014: audio/web. this paragraph to rem... [7]

3.5.4. "*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.

3.5.5. "*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.

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.

3.5.10. "*Predominant mode*" for the purposes of this gtr 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 shall 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 (0 °C).

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

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 gtr.

3.6.1. "Particle number" (PN) means the total number of solid particles emitted from the vehicle exhaust quantified according to the sampling and measurement approaches as specified in this gtr;

Comment [SMD38]: EXPERT PROPOSAL: 26.05.2015. From Barouch Giechaskiel (JRC). Definition agreed upon by the PMP group.

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

3.6.2. "*Particulate matter*" (PM) means any material collected on a specified filter medium after diluting the exhaust with clean filtered diluent to a temperature less than 325 K (52 °C); typically this is primarily carbon, condensed hydrocarbons, and sulphates with associated water;

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

3.6.2. "Particulate (matter) mass" (PM) means the mass of any material collected on the filter media from diluted vehicle exhaust quantified according to the sampling and measurement approaches as specified in this gtr.

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 Regulation No. 85.

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

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.

3.X.X. "*Fuel cell vehicle*" means.....

4. Abbreviations

4.1. General abbreviations

CFV	Critical flow venturi
CFO	Critical flow orifice
CLD	Chemiluminescent detector
CLA	Chemiluminescent analyser
CVS	Constant volume sampler
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

Comment [SMD39]: CONFIRMATION: March 2015 drafting meeting, Brussels.

Comment [SMD40]: EXPERT PROPOSAL: 11.02.2015. Proposed by B. Ramacher, supported by L. Hill.

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Comment [SMD41]: EXPERT PROPOSAL: 22.04.2015. From Les Hill, Stockholm IWG #10.

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Comment [SMD42]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD43]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD44]: CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Comment [SMD45]: CONFIRMATION: March 2015 drafting meeting. Deletion confirmed.

Comment [SMD46]: CONFIRMATION: April 2015 drafting meeting, Stockholm.

Comment [SMD47]: EXPERT PROPOSAL: 02.12.2014: proposal expected from W. Coleman as agreed upon during WLTP IWG #8 in Pune.

Comment [SMD48]: EXPERT PROPOSAL: March 2015 drafting meeting, Brussels. Japan proposes including the necessary definitions related to fuel cell.

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)
NG/biomethane	Natural gas/biomethane
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
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 gtr during its useful life.

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 responsible 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 Annex 3 to this gtr.

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 Annex 6 to this gtr.

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).

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

in considering an exemption shall 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 responsible authority.

5.6. Interpolation family

5.6.1. Only vehicles which are identical with respect to the following vehicle/ powertrain/transmission characteristics are permitted to be part of the same interpolation family.

(a) Type of internal combustion engine: fuel type, combustion type, engine displacement, full-load characteristics, engine technology, and charging system, and 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) and transmission model (e.g. torque rating, number of gears, number of clutches, etc.);

(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].

5.7. Road load family

Unless vehicles are identical with respect to the following characteristics, they shall not be considered to be part of the same road load family:

(a) Transmission type (e.g. manual, automatic, CVT) and transmission model (e.g. torque rating, number of gears, number of clutches, etc.). At the request of the manufacturer and with agreement of the responsible authority, a transmission that is better in terms of road load may be included in the family

(b) 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 25 per cent ;

(c) Number of powered axles;

(d) If at least one "electric machine" is coupled in the gearbox position "neutral" and the vehicle is not equipped with a coast down mode (paragraph 4.2.1.5.5. of Annex 4) such that the electric machine has no influence on the road load, the criteria from 5.6. (f) shall apply.

If there is a difference, which has a non-negligible influence on road load except mass, rolling resistance and aerodynamics, that vehicle shall not be

Comment [SMD49]: EXPERT PROPOSAL: 01.11.2014: From C. Lueginger and A. Feucht.

Comment [SMD50]: CONFIRMATION: March 2015 drafting meeting.

Comment [SMD51]: GTR CORRECTION: 25.05.2015: DC proposes replacing "that is better in terms of road load" with "with lower power losses".

Comment [SMD52]: EXPERT PROPOSAL: April 2015 drafting meeting. Point (e) must go to EV for approval.

Comment [SMD53]: EXPERT PROPOSAL: March 2015 drafting meeting.

considered to be part of the family unless approved by the responsible authority.

Comment [SMD54]: GTR CORRECTION: 25.05.2015: DC proposes:
If there is a difference apart from vehicle mass, rolling resistance and aerodynamics which has a non-negligible influence on road load, that vehicle shall not be considered to be part of the family unless approved by the responsible authority.

Comment [SMD55]: Will "non-negligible" have to be defined?

6. Performance requirements

6.1. Limit values

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.

6.2. Testing

Testing shall be performed according to:

(a) The WLTCs as described in Annex 1;

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

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

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

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

(f) The test procedures as described in Annexes 6 and 8;

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

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 3. Definitions and not that which may be artificially restricted.

2. Vehicle classifications

2.1. Class 1 vehicles have a power to unladen mass ratio $P_{mr} \leq 22$ 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 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.

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

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.

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.

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

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.

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

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 Annex 8) for Class 3a and Class 3b vehicles.

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

4. WLTC Class 1 vehicles

Figure A1/1
WLTC, Class 1 Vehicles, Phase Low_1

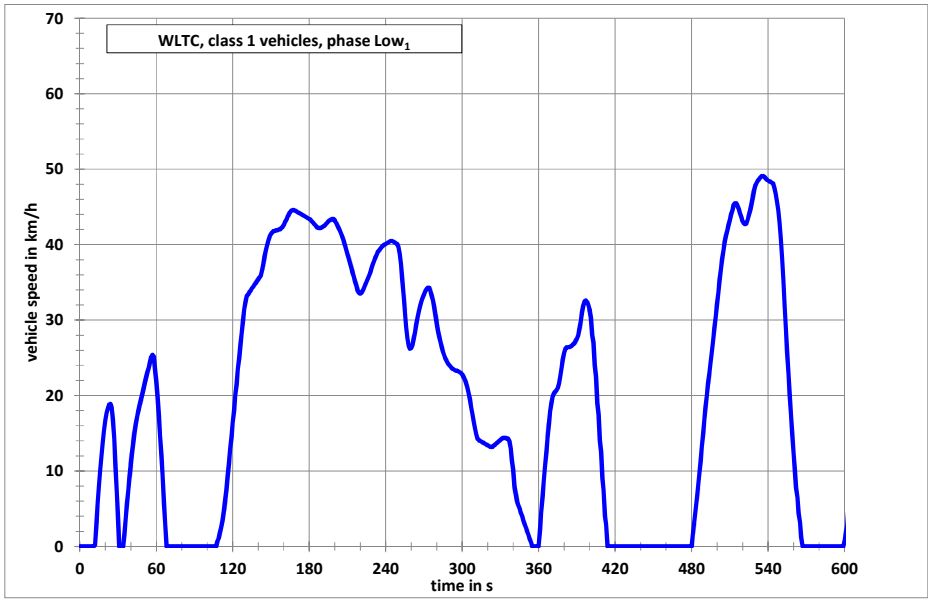


Figure A1/2
WLTC, Class 1 Vehicles, Phase $Medium_1$

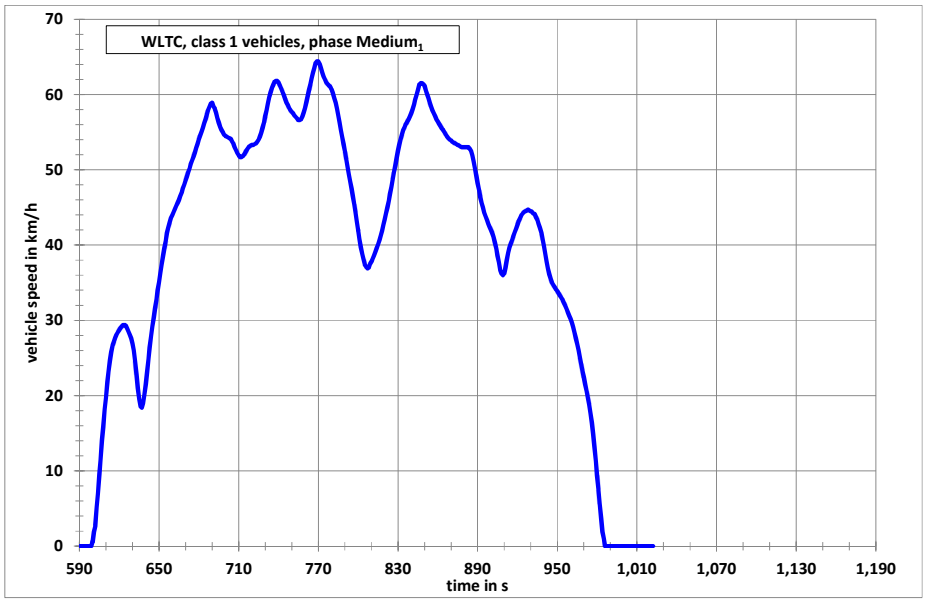


Table A1/1
WLTC, Class 1 Vehicles, Phase Low_1

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
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
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

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
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
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

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
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
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

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
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						

Table A1/2

WLTC, Class 1 Vehicles, Phase Medium$_1$

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
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
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

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
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
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						

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
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						
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

Figure A1/3
WLTC, Class 2 Vehicles, Phase Low_2

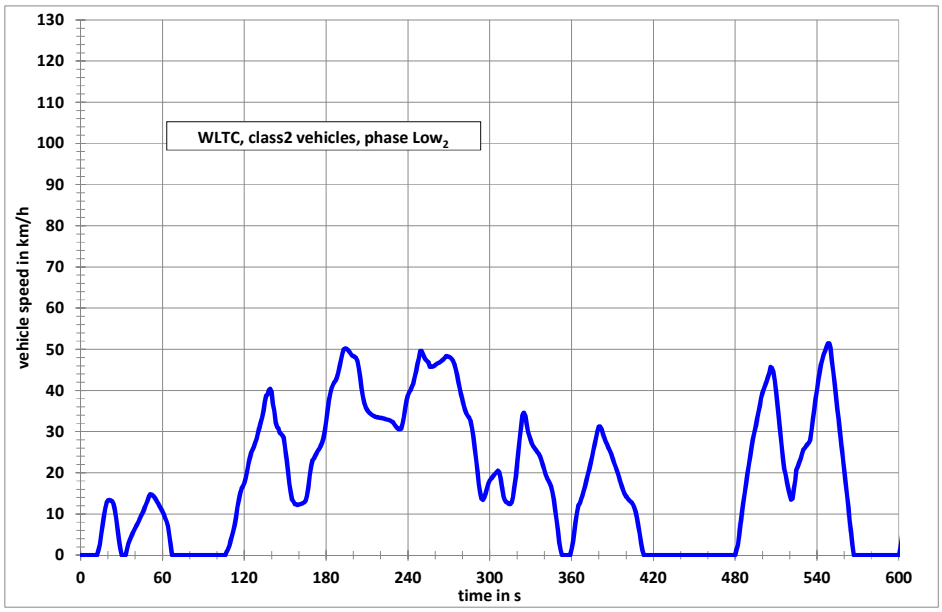


Figure A1/4
WLTC, Class 2 Vehicles, Phase $Medium_2$

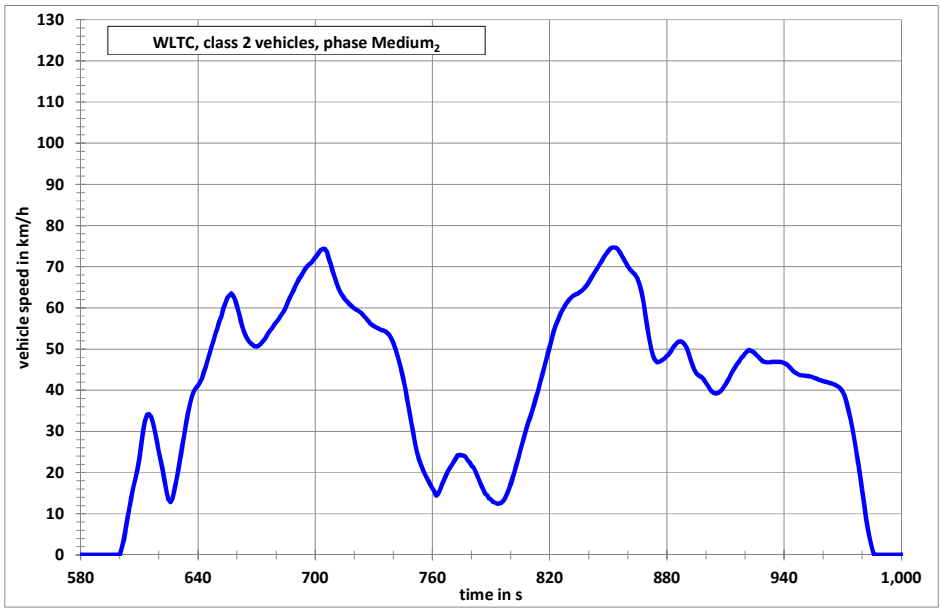


Figure A1/5
WLTC, Class 2 Vehicles, Phase High$_2$

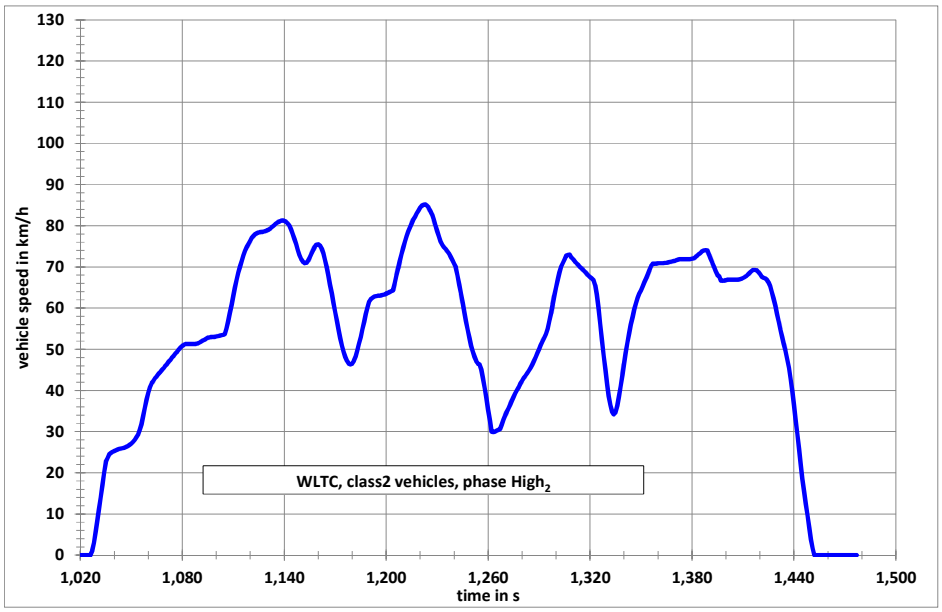


Figure A1/6
WLTC, Class 2 Vehicles, Phase Extra High$_2$

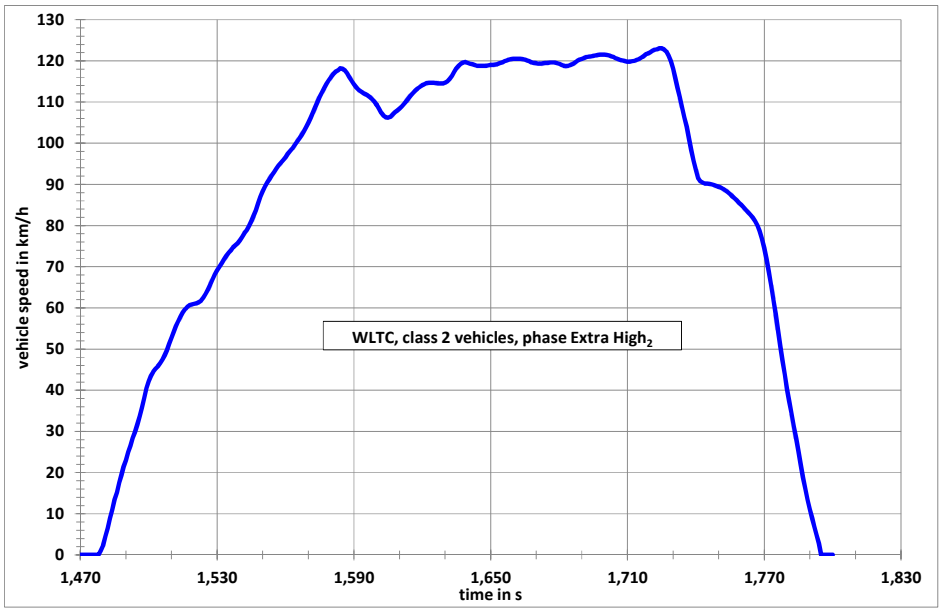


Table A1/3
WLTC, Class 2 Vehicles, Phase Low_2

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
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

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
188	43.2	237	33.5	286	32.5	335	25.0
189	44.4	238	35.8	287	30.9	336	24.6
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

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
384	28.6	433	0.0	482	2.5	531	26.0
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

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
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						

Table A1/4
WLTC, Class 2 Vehicles, Phase Medium$_2$

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	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
826	59.0	875	46.8	924	49.3	973	35.1

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
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						
1022	0.0						

Table A1/5
WLTC, Class 2 Vehicles, Phase High$_2$

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	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
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

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
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
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

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
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						
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$_2$

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
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

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
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				
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

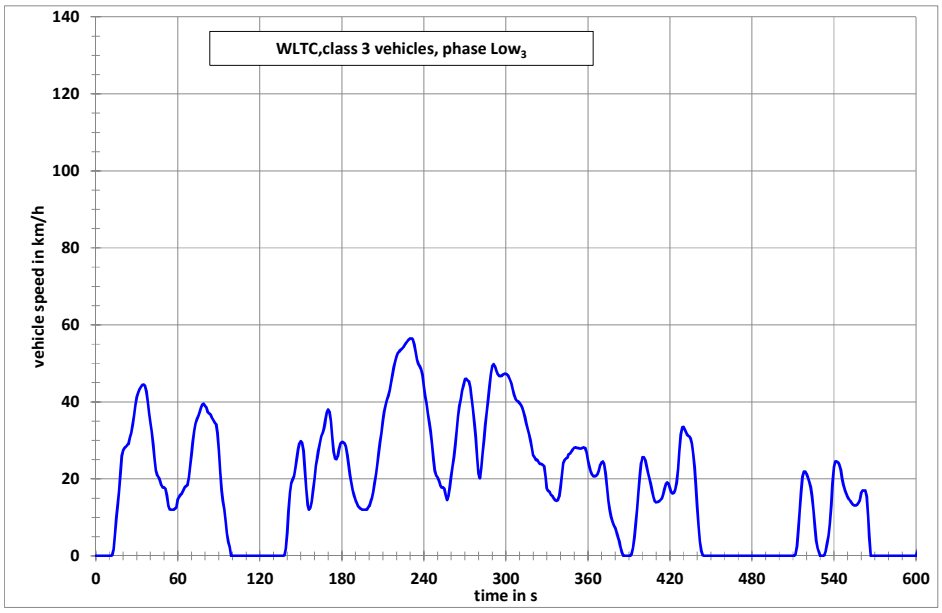


Figure A1/8
WLTC, Class 3 Vehicles, Phase $Medium_{3-1}$

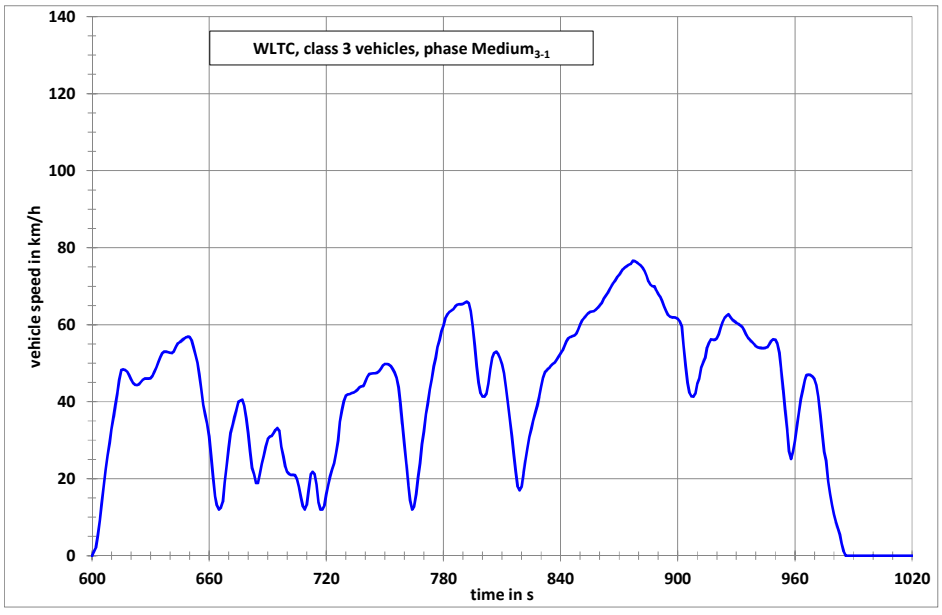


Figure A1/9
WLTC, Class 3 Vehicles, Phase Medium$_{3-2}$

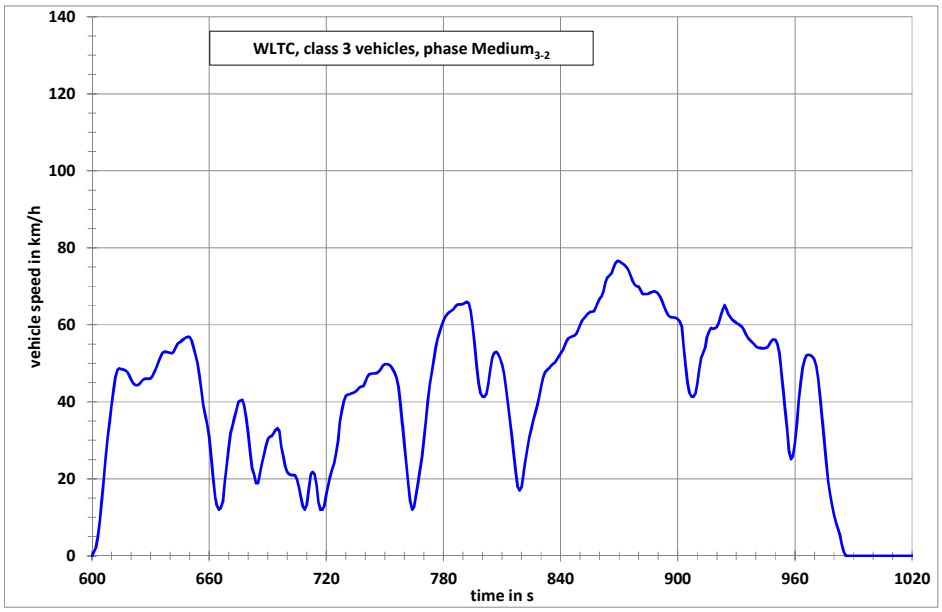


Figure A1/10
WLTC, Class 3 Vehicles, Phase High$_{3-1}$

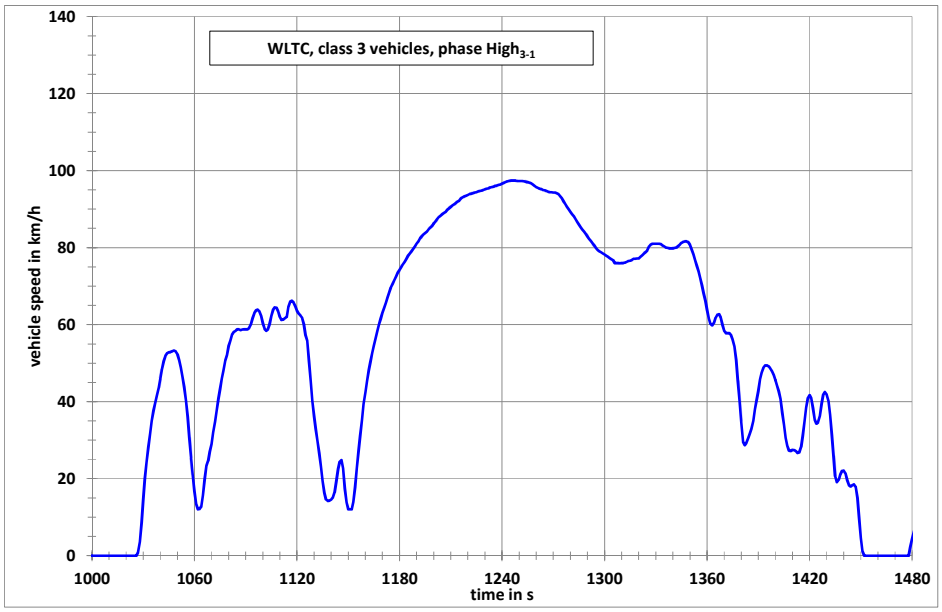


Figure A1/11
WLTC, Class 3 Vehicles, Phase $High_{3-2}$

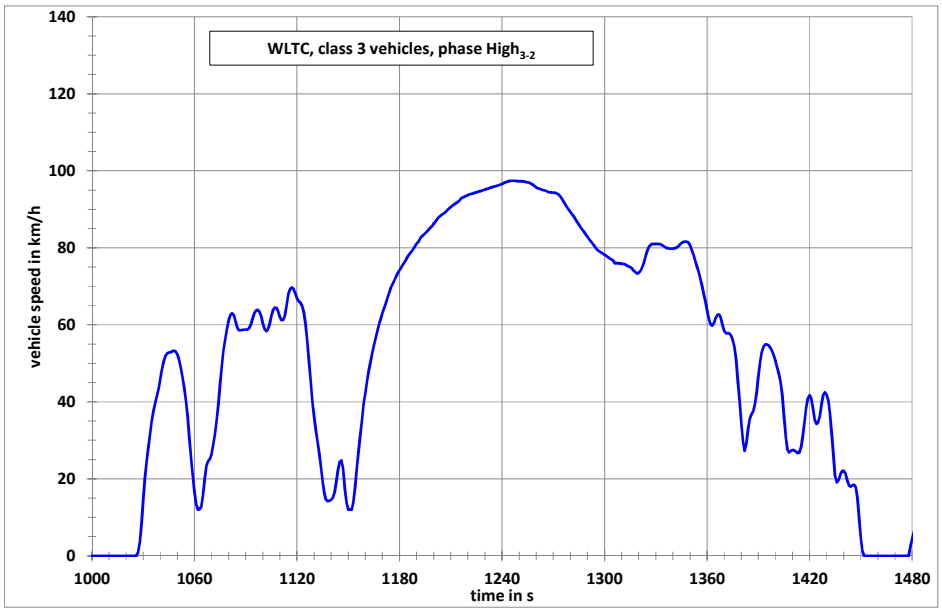


Figure A1/12
WLTC, Class 3 Vehicles, Phase Extra $High_3$

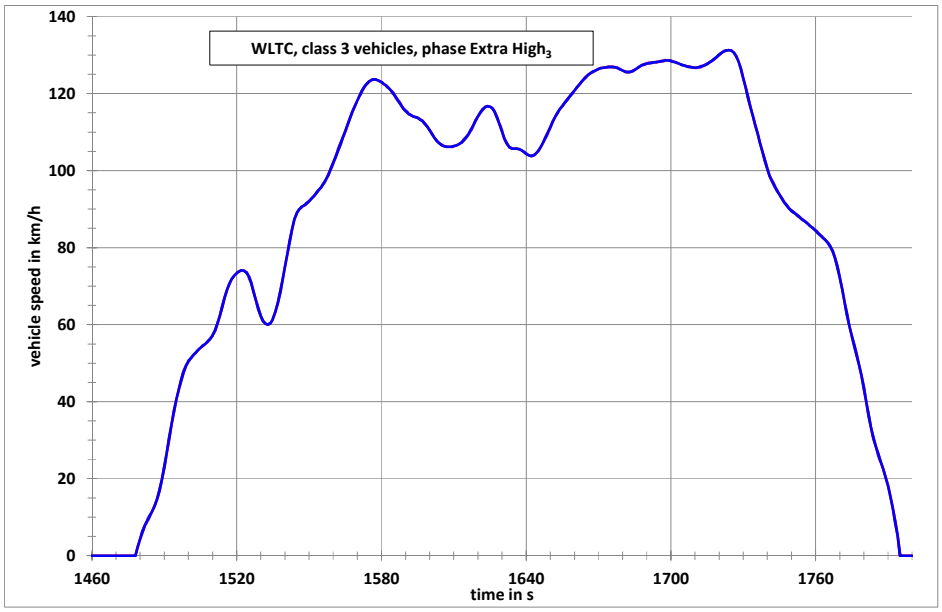


Table A1/7
WLTC, Class 3 Vehicles, Phase Low_3

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
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

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
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
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

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
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
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

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
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						

Table A1/8
WLTC, Class 3 Vehicles, Phase Medium$_{3\text{-}1}$

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
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
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

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	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
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

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
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						
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
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

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	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
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

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
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						
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 $High_{3-1}$

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
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

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
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
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

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
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				
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
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

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
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
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

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
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				
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$_3$

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
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

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
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		
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.

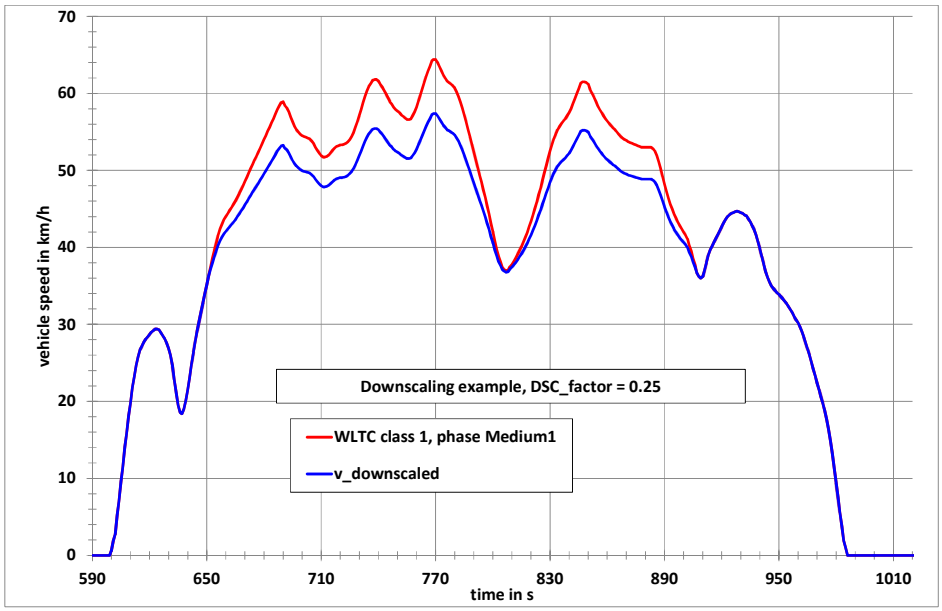
This paragraph shall not apply to vehicles tested according to Annex 8.

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:

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

where:

v_i is the vehicle speed, km/h;

i is the time between second 651 and second 906.

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

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

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:

$$f_{corr_dec} = \frac{v_{dsc_848} - 36.7}{v_{orig_848-} - 36.7} \quad (4)$$

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:

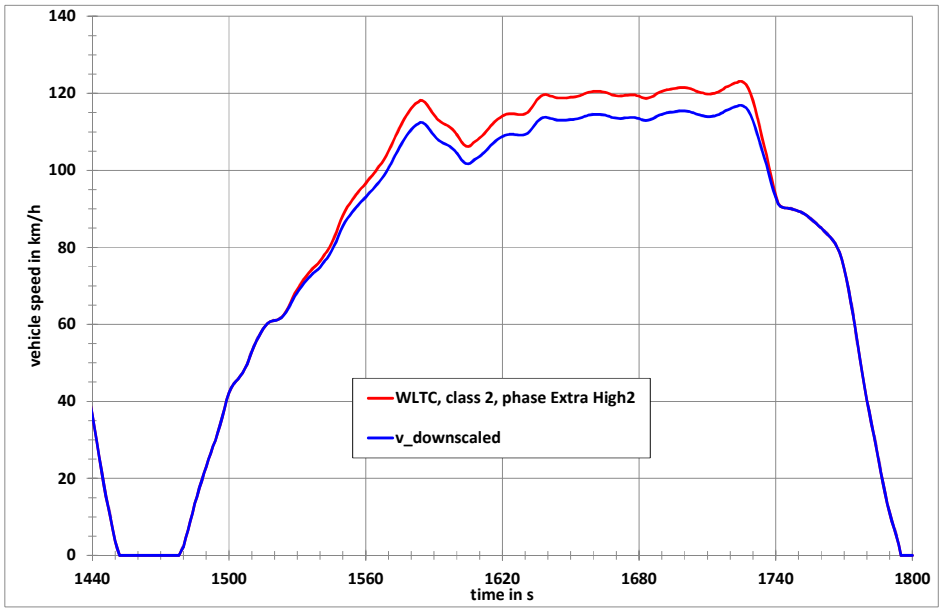
$$v_{dsc_i} = v_{dsc_{i-1}} + a_{orig_{i-1}} \times f_{corr_dec} \times 3.6 \quad (5)$$

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



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:

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

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:

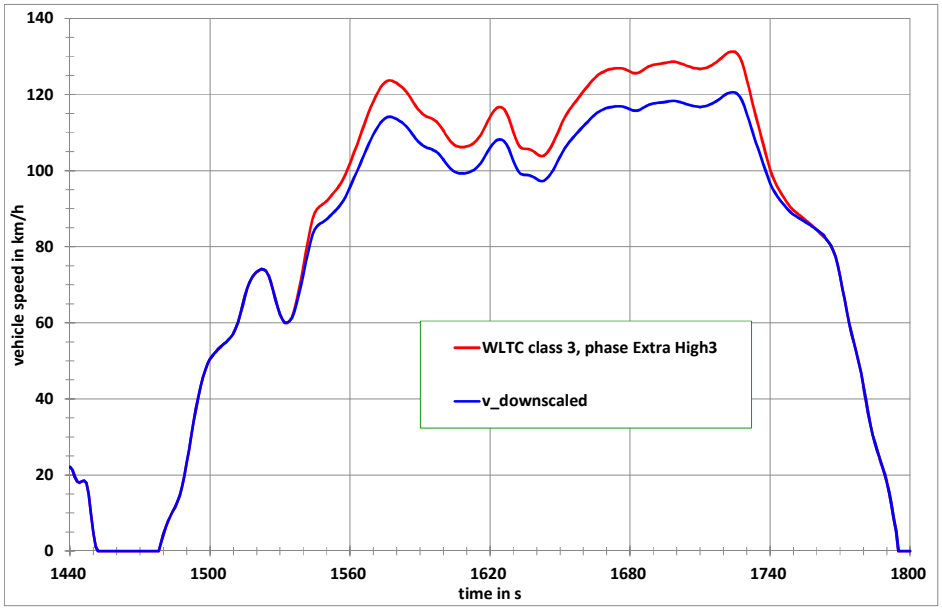
$$v_{dsc_i} = v_{dsc_{i-1}} + a_{orig_{i-1}} \times f_{corr_dec} \times 3.6 \quad (10)$$

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.

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:

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

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.

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 and the corresponding vehicle speed, v_i, in the cycle trace and is calculated as follows:

$$P_{req,max,i} = \frac{\left((f_0 \times v_i) + (f_1 \times v_i^2) + (f_2 \times v_i^3) + (1.03 \times TM \times v_i \times a_i)\right)}{3600} \quad (16)$$

where:

f_0 is the constant road load coefficient, N;

f_1 is the first order road load coefficient, N/(km/h);

f_2 is the second order road load coefficient, N/(km/h)^2;

TM is the test mass, kg;

v_i is the speed at time i, km/h.

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.

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

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 $r_0 = 0.978, a_1 = 0.680, b_1 = -0.665$

Class 2 $r_0 = 0.866, a_1 = 0.606, b_1 = -0.525.$

Class 3 $r_0 = 0.867, a_1 = 0.588\ b_1 = -0.510.$

The resulting f_{dsc} is mathematically rounded to 3 places of decimal and is applied only if it exceeds 0.010.

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 Annex 4 shall be used for the determination of the downscaling factor and the resulting downscaled cycle shall be used for all measurements.

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.

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 Annex shall apply to vehicles equipped with manual 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 engine speeds and full load power curves versus engine speed.

1.4. For vehicles equipped with a two-range transmission (low and high), only the range designed for normal on-road operation shall be considered for gear use determination.

1.5 This annex shall not apply to vehicles tested according to 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, kW;

(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 minimum of this range, min^{-1};

(c) n_{idle}, idling speed, min^{-1};

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

(e) n_{min_drive}, minimum engine speed when the vehicle is in motion, min^{-1}

for $n_{gear} = 1$, $n_{min_drive} = n_{idle}$, (1)

for $n_{gear} = 2$,

for transitions from 1st to 2nd gear during accelerations from standstill:

$n_{min_drive} = 1.15 \times n_{idle}$

for all other driving conditions:

.

$n_{min_drive} = 0.9 \times n_{idle}$, (2)

for $n_{gear} > 2$, n_{min_drive} is determined by :

$n_{min_drive} = n_{idle} + 0.125 \times (s - n_{idle})$ (3)

Higher values may be used if requested by the manufacturer.

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

(g) TM, test mass of the vehicle selected for testing, kg;

(h) f_0, f_1, f_2, road load coefficients selected for testing, N, N/(km/h), and N/(km/h)² respectively;

(i) ng_{vmax}, the gear in which the maximum vehicle speed is reached, and is determined as follows:

If $v_{max}(ng_{max}) \geq v_{max}(ng_{max}\text{-}1)$, then,

$ng_{vmax} = ng_{max}$ (4)

otherwise, $ng_{vmax} = ng_{max} - 1$ (5)

where:

$v_{max}(ng_{max})$ is the vehicle speed at which the required road load power equals the available power P_{wot} in gear ng_{max};

$v_{max}(ng_{max}\text{-}1)$ is the vehicle speed at which the required road load power equals the available power P_{wot} in the next lower gear.

The required road load power, kW, at second j, shall be calculated as follows:

$$P_{required} = 0.9 \times \frac{f_0 \times v_j + f_1 \times v_j^2 + f_2 \times v_j^3}{3600} \quad (6)$$

where:

v_j is the vehicle speed at second j of the cycle trace, km/h.

(j) n_{max_95} is the minimum engine speed where 95 per cent of rated power is reached, min^{-1};

(k) $n_{max}(ng_{vmax}) = ndv(ng_{vmax}) \times v_{max,cycle}$ (7)

where:

$v_{max,cycle}$ is the maximum speed of the vehicle speed trace according to Annex 1, km/h;

(l) n_{max} is the maximum of n_{max_95} and $n_{max}(ng_{vmax})$, min^{-1};

(m) $p_{wot(n)}$ is the full load power curve over the engine speed range from idling speed to n_{max};

The power curve shall consist of a sufficient number of data sets (n, Pwot) so that the calculation of interim points between consecutive data sets can be performed by linear interpolation. The first data set shall be at n_{idle} and the last one at n_{max} or higher. There is no need for the data sets to be equally spaced.

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

3.1. Calculation of required power

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

$$P_{required,j} = \left(\frac{f_0 \times v_j + f_1 \times v_j^2 + f_2 \times v_j^3}{3600}\right) + \frac{kr \times a_j \times v_j \times TM}{3600} \quad (8)$$

where:

f_0 is the constant road load coefficient, N;

f_1 is the first order road load coefficient, N/(km/h);

f_2 is the second order road load coefficient, 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, $a_j = \frac{(v_{j+1} - v_j)}{3.6 \times (t_{j+1} - t_j)}$; (9)

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 1.03.

3.2. Determination of engine speeds

For any $v_j \leq 1$ km/h, it shall be assumed that the vehicle is standing still and the engine speed shall be set to n_{idle}.The gear lever shall be placed in neutral with the clutch engaged except 1 second before beginning an acceleration phase from standstill where first gear shall be selected with the clutch disengaged.

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:

$$n_{i,j} = ndv_i \times v_j \quad (10)$$

3.3. Selection of possible gears with respect to engine speed

The following gears may be selected for driving the speed trace at v_j:

(a) all gears $i < ng_{vmax}$ where $n_{min_drive} \leq n_{i,j} \leq n_{max_95}$, and

(b) all gears $i \geq ng_{vmax}$ where $n_{min_drive} \leq n_{i,j} \leq n_{max}(ng_{vmax})$

If $a_j \leq 0$ and $n_{i,j}$ drops below n_{idle}, $n_{i,j}$ shall be set to n_{idle} and the clutch shall be disengaged.

If $a_j > 0$ and $n_{i,j}$ drops below $(1.15 \times n_{idle})$, $n_{i,j}$ shall be set to $(1.15 \times n_{idle})$ and the clutch shall be disengaged.

3.4. 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:

$$P_{available_i,j} = P_{wot}(n_{i,j}) \times (1 - (SM + ASM)) \quad (11)$$

where:

P_{rated} is the rated power, kW;

P_{wot} is the power available at $n_{i,j}$ at full load condition from the 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 10 per cent;

ASM ASM is an additional exponential power safety margin, which may be applied at the request of the manufacturer. ASM is fully effective between n_{idle} and n_{start}, and exponentially approaching 0 at n_{end} as described by the following requirements:

If $n \leq n_{start}$, then $ASM = ASM_0$, (12)

If $n > n_{start}$, then:

$$ASM = ASM_0 \times \exp(\ln(0.005/ASM_0) \times (n_{start} - n)/(n_{start} - n_{end})) \quad (13)$$

ASM_0, n_{start} and n_{end} shall be defined by the manufacturer but shall fulfil the following conditions:

$n_{start} \geq n_{idle}$,

$n_{end} > n_{start}$.

3.5. Determination of possible gears to be used

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

(a) The conditions of paragraph 3.3. are fulfilled, and

(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.

An acceleration phase is a time period of more than 3 seconds with a vehicle speed ≥ 1 km/h and with monotonic increase of vehicle speed. A deceleration phase is a time period of more than 3 seconds with a vehicle speed ≥ 1 km/h and with monotonic decrease of vehicle speed.

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

(a) If a lower gear is required at a higher vehicle speed during an acceleration phase, 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 shall be corrected to 2, 2, 2, 2, 2, 2, 2, 3.

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

(c) During a deceleration phase, gears with $n_{gear} > 2$ shall be used as long as the engine speed does not drop below n_{min_drive}. If the duration of a gear sequence is only 1 second, it shall be replaced by gear 0 and the clutch shall be disengaged. If the duration of a gear sequence is 2 seconds, it shall be replaced by gear 0 for the 1st second and ~~the next lower gear~~ for the 2nd second with the gear that follows after the 2 second period. The clutch shall be disengaged for the 1st second.

Example: A gear sequence 5, 4, 4, 2 shall be replaced by 5, 0, 2, 2.

(d) The second gear shall be used during a deceleration phase within a short trip of the cycle as long as the engine speed does not drop below $0.9 \times n_{idle}$. If the engine speed drops below n_{idle}, the clutch should be disengaged.

(e) If the deceleration phase is the last part of a short trip shortly before a stop phase and the second gear would only be used for up to two seconds, the gear shall be set to 0 and the clutch may be either disengaged or the gear lever placed in neutral and the clutch left engaged. A downshift to first gear is not permitted during those deceleration phases.

(f) If gear i is used for a time sequence of 1 to 5 seconds and the gear before this sequence is lower and the gear after this sequence is the same as or lower than the gear before this sequence, the gear for the sequence shall be corrected to the gear before the sequence.

Examples:

(i) gear sequence $i-1, i, i-1$ shall be replaced by $i-1, i-1, i-1$;

(ii) gear sequence $i-1, i, i, i-1$ shall be replaced by $i-1, i-1, i-1, i-1$;

(iii) gear sequence $i-1, i, i, i, i-1$ shall be replaced by $i-1, i-1, i-1, i-1, i-1, i-1$;

(iv) gear sequence $i-1, i, i, i, i, i-1$ shall be replaced by $i-1, i-1, i-1, i-1, i-1, i-1$;

(v) gear sequence $i-1, i, i, i, i, i, i-1$ shall be replaced by $i-1, i-1, i-1, i-1, i-1, i-1, i-1$.

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

Paragraphs 4.(a) to 4.(f) inclusive shall be applied sequentially and only after each has completely finished scanning the gear profile. Since the above modifications may create new gear use sequences which are in conflict with these requirements, the gear sequences shall be checked for practicality three times and modified if necessary.

Annex 3

Reference fuels

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 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

3.1. Gasoline/Petrol (nominal 90 RON, E0)

Table A3/1
Gasoline/Petrol (nominal 90 RON, E0)

Fuel Property or Substance Name	Unit	Standard		Test method
		Minimum	Maximum	
Research octane number, RON		90	92	JIS K2280
Motor octane number, MON		80	82	JIS K2280
Density	g/cm³	0.720	0.734	JIS K2249
Vapour pressure	kPa	56	60	JIS K2258
Distillation:				
— 10 % distillation temperature	K (°C)	318 (45)	328 (55)	JIS K2254
— 50 % distillation temperature	K (°C)	363 (90)	373 (100)	JIS K2254
— 90 % distillation temperature	K (°C)	413 (140)	443 (170)	JIS K2254
— final boiling point	K (°C)		488 (215)	JIS K2254
— olefins	% v/v	15	25	JIS K2536-1 JIS K2536-2
— aromatics	% v/v	20	45	JIS K2536-1 JIS K2536-2 JIS K2536-3
— benzene	% v/v		1.0	JIS K2536-2 JIS K2536-3 JIS K2536-4
Oxygen content		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-6
Existent gum	mg/100ml		5	JIS K2261
Sulphur content	Wt ppm		10	JIS K2541-1 JIS K2541-2 JIS K2541-6 JIS K2541-7
Lead content		not to be detected		JIS K2255
Ethanol		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-6
Methanol		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-5 JIS K2536-6
MTBE		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-5 JIS K2536-6
Kerosene		not to be detected		JIS K2536-2 JIS K2536-4

3.2. Gasoline/petrol (nominal 91 RON, E0)

Table A3/2
Gasoline/petrol (nominal 91 RON, E0)

Fuel Property or Substance Name	Unit		Standard		Test method
			Minimum	Maximum	
Research octane number, RON			91	94	KS M 2039
Vapour pressure	kPa	Summer	44	60	KS M ISO 3007
		Winter	44	96	
Distillation:					
— 10 % distillation temperature	°C		-	70	ASTM D86
— 50 % distillation temperature	°C		-	125	ASTM D86
— 90 % distillation temperature	°C		-	170	ASTM D86
— final boiling point	°C		-	225	ASTM D86
Residue	% v/v		-	2.0	ASTM D86
Water content	% v/v		-	0.01	KS M 2115
— olefins[(1)]	% v/v		-	16(19)	KS M 2085, ASTM D6296,D6293,D6839
— aromatics[(1)]	% v/v		-	24 (21)	KS M 2407, ASTM D3606, D5580,D6293,D6839,PIONA
— benzene	% v/v		-	0.7	KS M 2407, ASTM D3606, D5580,D6293,D6839,PIONA
Oxygen content	wt %		-	2.3	KS M 2408, ASTM D4815, D6839
Unwashed gum	mg/100ml		-	5	KS M 2041
Sulphur content	wt ppm		-	10	KS M 2027, ASTM D5453
Lead content	mg/L		-	13	KS M 2402, ASTM D3237
Phosphorus content	mg/L		-	1.3	KS M 2403, ASTM D3231
Methanol	wt %		-	0.01	KS M 2408
Oxidation stability	min		480	-	KS M 2043
Copper corrosion	50℃, 3h		-	1	KS M 2018
Colour	Yellow		-	-	Sensory test

(1) The standard in brackets may apply for olefins. In this case, the value in brackets for aromatics shall apply.

3.3. Gasoline/petrol (nominal 100 RON, E0)

Table A3/3
Gasoline/petrol (nominal 100 RON, E0)

Fuel Property or Substance Name	Unit	Standard		Test method
		Minimum	Maximum	
Research octane number, RON		99	101	JIS K2280
Motor octane number, MON		86	88	JIS K2280
Density	g/cm³	0.740	0.754	JIS K2249
Vapour pressure	kPa	56	60	JIS K2258
Distillation:				
— 10 % distillation temperature	K (°C)	318 (45)	328 (55)	JIS K2254
— 50 % distillation temperature	K (°C)	363 (90)	373 (100)	JIS K2254
— 90 % distillation temperature	K (°C)	413 (140)	443 (170)	JIS K2254
— final boiling point	K (°C)		488 (215)	JIS K2254
— olefins	% v/v	15	25	JIS K2536-1 JIS K2536-2
— aromatics	% v/v	20	45	JIS K2536-1 JIS K2536-2 JIS K2536-3
— benzene	% v/v		1.0	JIS K2536-2 JIS K2536-3 JIS K2536-4
Oxygen content		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-6
Existent gum	mg/100ml		5	JIS K2261
Sulphur content	Wt ppm		10	JIS K2541-1 JIS K2541-2 JIS K2541-6 JIS K2541-7
Lead content		not to be detected		JIS K2255
Ethanol		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-6
Methanol		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-5 JIS K2536-6
MTBE		not to be detected		JIS K2536-2 JIS K2536-4 JIS K2536-5 JIS K2536-6
Kerosene		not to be detected		JIS K2536-2 JIS K2536-4

3.4. Gasoline/petrol (nominal 94 RON, E0)

Table A3/4
Gasoline/petrol (nominal 94 RON, E0)

Fuel Property or Substance Name	Unit		Standard		Test method
			Minimum	Maximum	
Research octane number, RON			94	-	KS M 2039
Vapour pressure	kPa	Summer	44	60	KS M ISO 3007
		Winter	44	96	
Distillation:					
— 10 % distillation temperature	°C		-	70	ASTM D86
— 50 % distillation temperature	°C		-	125	ASTM D86
— 90 % distillation temperature	°C		-	170	ASTM D86
— final boiling point	°C		-	225	ASTM D86
Residue	% v/v			2.0	ASTM D86
Water content	% v/v			0.01	KS M 2115
— olefins[(1)]	% v/v			16 (19)	KS M 2085, ASTM D6296,D6293,D6839
— aromatics[(1)]	% v/v			24 (21)	KS M 2407, ASTM D3606, D5580,D6293,D6839,PIONA
— benzene	% v/v			0.7	KS M 2407, ASTM D3606, D5580,D6293,D6839,PIONA
Oxygen content	wt %			2.3	KS M 2408, ASTM D4815, D6839
Unwashed gum	mg/100ml			5	KS M 2041
Sulphur content	wt ppm			10	KS M 2027, ASTM D5453
Lead content	mg/L			13	KS M 2402, ASTM D3237
Phosphorus content	mg/L			1.3	KS M 2403, ASTM D3231
Methanol	wt %			0.01	KS M 2408
Oxidation stability	min		480	-	KS M 2043
Copper corrosion	50℃, 3h			1	KS M 2018
Colour	Green		-	-	Sensory Test

(1) The standard in brackets may apply for olefins. In this case, the value in brackets for aromatics shall apply.

3.5. Gasoline/petrol (nominal 95 RON, E5)

Table A3/5
Gasoline/petrol (nominal 95 RON, E5)

Parameter	Unit	Limits [1]		Test method
		Minimum	Maximum	
Research octane number, RON		95.0		EN 25164 EN ISO 5164
Motor octane number, MON		85.0		EN 25163 EN ISO 5163
Density at 15 °C	kg/m^3	743	756	EN ISO 3675 EN ISO 12185
Vapour pressure	kPa	56.0	60.0	EN ISO 13016-1 (DVPE)
Water content	% v/v		0.015	ASTM E 1064
Distillation:				
— evaporated at 70 °C	% v/v	24.0	44.0	EN-ISO 3405
— evaporated at 100 °C	% v/v	48.0	60.0	EN-ISO 3405
— evaporated at 150 °C	% v/v	82.0	90.0	EN-ISO 3405
— final boiling point	°C	190	210	EN-ISO 3405
Residue	% v/v		2.0	EN-ISO 3405
Hydrocarbon analysis:				
— olefins	% v/v	3.0	13.0	ASTM D 1319
— aromatics	% v/v	29.0	35.0	ASTM D 1319
— benzene	% v/v		1.0	EN 12177
— saturates	% v/v	To be recorded		ASTM 1319
Carbon/hydrogen ratio		To be recorded		
Carbon/oxygen ratio		To be recorded		
Induction period [2]	minutes	480		EN-ISO 7536
Oxygen content [3]	% m/m	To be recorded		EN 1601
Existent gum	mg/ml		0.04	EN-ISO 6246
Sulphur content [4]	mg/kg		10	EN ISO 20846 EN ISO 20884
Copper corrosion			Class 1	EN-ISO 2160
Lead content	mg/l		5	EN 237
Phosphorus content [5]	mg/l		1.3	ASTM D 3231
Ethanol [3]	% v/v	4.7	5.3	EN 1601 EN 13132

(1) The values quoted in the specifications are 'true values'. In establishing of their limit values the terms of ISO 4259 "Petroleum products — Determination and application of precision data in relation to methods of test" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

(2) The fuel may contain oxidation inhibitors and metal deactivators normally used to stabilise refinery gasoline streams, but detergent/dispersive additives and solvent oils shall not be added.

(3) Ethanol meeting the specification of EN 15376 is the only oxygenate that shall be intentionally added to the reference fuel.

(4) The actual sulphur content of the fuel used for the Type 1 test shall be recorded.

(5) There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.

3.6. Gasoline/petrol (nominal 95 RON, E10)

Table A3/6
Gasoline/petrol (nominal 95 RON, E10)

Parameter	Unit	Limits [1]		Test method[2]
		Minimum	Maximum	
Research octane number, RON [3]		95.0	98.0	EN ISO 5164
Motor octane number, MON [3]		85.0	89.0	EN ISO 5163
Density at 15 °C	kg/m^3	743.0	756.0	EN ISO 12185
Vapour pressure	kPa	56.0	60.0	EN 13016-1
Water content	% v/v	max 0.05 Appearance at -7 °C: clear and bright		EN 12937
Distillation:				
— evaporated at 70 °C	% v/v	34.0	46.0	EN-ISO 3405
— evaporated at 100 °C	% v/v	54.0	62.0	EN-ISO 3405
— evaporated at 150 °C	% v/v	86.0	94.0	EN-ISO 3405
— final boiling point	°C	170	195	EN-ISO 3405
Residue	% v/v		2.0	EN-ISO 3405
Hydrocarbon analysis:				
— olefins	% v/v	6.0	13.0	EN 22854
— aromatics	% v/v	25.0	32.0	EN 22854
— benzene	% v/v		1.00	EN 22854 EN 238
— saturates	% v/v	To be recorded		EN 22854
Carbon/hydrogen ratio		To be recorded		
Carbon/oxygen ratio		To be recorded		
Induction period [4]	minutes	480		EN-ISO 7536
Oxygen content [5]	% m/m	3.3	3.7	EN 22854
Solvent washed gum (Existent gum content)	mg/100ml		4	EN-ISO 6246
Sulphur content [6]	mg/kg		10	EN ISO 20846 EN ISO 20884
Copper corrosion			Class 1	EN-ISO 2160
Lead content	mg/l		5	EN 237
Phosphorus content [7]	mg/l		1.3	ASTM D 3231
Ethanol [5]	% v/v	9.0	10.0	EN 22854

(1) The values quoted in the specifications are 'true values'. In establishing of their limit values the terms of ISO 4259 "Petroleum products - Determination and application of precision data in relation to methods of test" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).
Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

(2) Equivalent EN/ISO methods will be adopted when issued for properties listed above.

(3) A correction factor of 0.2 for MON and RON shall be subtracted for the calculation of the final result in accordance with EN 228:2008.

(4) The fuel may contain oxidation inhibitors and metal deactivators normally used to stabilise refinery gasoline streams, but detergent/dispersive additives and solvent oils shall not be added.

(5) Ethanol is the only oxygenate that shall be intentionally added to the reference fuel. The Ethanol used shall conform to EN 15376.

(6) The actual sulphur content of the fuel used for the Type 1 test shall be recorded.

(7) There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.

3.7. Ethanol (nominal 95 RON, E85)

Table A3/7
Ethanol (nominal 95 RON, E85)

Parameter	Unit	Limits [1]		Test method[2]
		Minimum	Maximum	
Research octane number, RON		95		EN ISO 5164
Motor octane number, MON		85		EN ISO 5163
Density at 15 °C	kg/m^3	To be recorded		ISO 3675
Vapour pressure	kPa	40	60	EN ISO 13016-1 (DVPE)
Sulphur content [3][4]	mg/kg		10	EN ISO 20846 EN ISO 20884
Oxidation stability	minutes	360		EN ISO 7536
Existent gum content (solvent washed)	mg/100ml		5	EN-ISO 6246
Appearance: This shall be determined at ambient temperature or 15 °C whichever is higher.		Clear and bright, visibly free of suspended or precipitated contaminants		Visual inspection
Ethanol and higher alcohols [7]	% v/v	83	85	EN 1601 EN 13132 EN 14517
Higher alcohols (C3-C8)	% v/v		2	
Methanol	% v/v		0.5	
Petrol [5]	% v/v	Balance		EN 228
Phosphorus	mg/l	0.3 [6]		ASTM D 3231
Water content	% v/v		0.3	ASTM E 1064
Inorganic chloride content	mg/l		1	ISO 6227
pHe		6.5	9	ASTM D 6423
Copper strip corrosion (3h at 50 °C)	Rating	Class 1		EN ISO 2160
Acidity, (as acetic acid CH3COOH)	% (m/m) (mg/l)		0.005-40	ASTM D 1613
Carbon/hydrogen ratio		Record		
Carbon/oxygen ratio		Record		

(1) The values quoted in the specifications are 'true values'. In establishing of their limit values the terms of ISO 4259 "Petroleum products — Determination and application of precision data in relation to methods of test" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

(2) In cases of dispute, the procedures for resolving the dispute and interpretation of the results based on test method precision, described in EN ISO 4259 shall be used.

(3) In cases of national dispute concerning sulphur content, either EN ISO 20846 or EN ISO 20884 shall be called up (similar to the reference in the national Annex of EN 228).

(4) The actual sulphur content of the fuel used for the Type 1 test shall be recorded.

(5) The unleaded petrol content can be determined as 100 minus the sum of the percentage content of water and alcohols.

(6) There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.

(7) Ethanol to meet specification of EN 15376 is the only oxygenate that shall be intentionally added to this reference fuel.

4. Gaseous fuels for positive ignition engines

4.1. LPG (A and B)

Table A3/8
LPG (A and B)

Parameter	Unit	Fuel E1	Fuel E2	Fuel J	Fuel K	Test method
Composition:						ISO 7941
C3-content	% vol	30 ± 2	85 ± 2		Winter: min 15, max 35 Summer: max 10	KS M ISO 7941
Propane and propylene content	% mole			Min 20, max 30		JIS K2240
C4-content	% vol	Balance			Winter: min 60, Summer: min 85	KS M ISO 7941
Butane and butylene content				Min 70, max 80		JIS K2240
Butadiene					max 0.5	KS M ISO 7941
< C3, > C4	% vol	Max 2	Max 2			
Olefins	% vol	Max 12	Max 15			
Evaporation residue	mg/kg	Max 50	Max 50			EN 15470
Evaporation residue (100ml)	ml	-			0.05	ASTM D2158
Water at 0 °C		Free				EN 15469
Total sulphur content	mg/kg	Max 10	Max 10			ASTM 6667
					Max 40	KS M 2150, ASTM D4486, ASTM D5504
Hydrogen sulphide		None	None			ISO 8819
Copper strip corrosion	rating	Class 1	Class 1			ISO 6251 [(1)]
Copper corrosion	40℃, 1h	-			1	KS M ISO 6251
Odour		Characteristic				
Motor octane number		Min 89	Min 89			EN 589 Annex B
Vapour pressure(40℃)	MPa	-	1.27			KS M ISO 4256 KS M ISO 8973
Density(15℃)	kg/m³	500			620	KS M 2150, KS M ISO 3993 KS M ISO 8973

(1) This method may not accurately determine the presence of corrosive materials if the sample contains corrosion inhibitors or other chemicals which diminish the corrosivity of the sample to the copper strip. Therefore, the addition of such compounds for the sole purpose of biasing the test method is prohibited.

4.2. NG/biomethane

4.2.1. "G20""High Gas" (nominal 100 % Methane)

Table A3/9
"G20" "High Gas" (nominal 100 per cent Methane)

Characteristics	Units	Basis	Limits		Test method
			Minimum	Maximum	
Composition:					
Methane	% mole	100	99	100	ISO 6974
Balance [1]	% mole	—	—	1	ISO 6974
N_2	% mole				ISO 6974
Sulphur content	$mg/m^{3(2)}$	—	—	10	ISO 6326-5
Wobbe Index (net)	$MJ/m^{3(3)}$	48.2	47.2	49.2	

(1) Inerts (different from N_2) + C2 + C2+.
(2) Value to be determined at 293.15 K (20 °C) and 101.325 kPa.
(3) Value to be determined at 273.15 K (0 °C) and 101.325 kPa.

4.2.2. "K-Gas" (nominal 88 % Methane)

Table A3/10
"K-Gas" (nominal 88 per cent Methane)

Characteristics	Units	Limits		Test method
		Minimum	Maximum	
Methane	% v/v	88.0	-	KS M ISO 6974, ASTM D1946, ASTM D1945-81, JIS K 0114
Ethane	% v/v	-	7.0	KS M ISO 6974, ASTM D1946, ASTM D1945-81, JIS K 0114
C_3 + hydrocarbon	% v/v	-	5.0	KS M ISO 6974, ASTM D1946, ASTM D1945-81, JIS K 0114
C_6 + hydrocarbon	% v/v	-	0.2	KS M ISO 6974, ASTM D1946, ASTM D1945-81, JIS K 0114
Sulphur content	ppm	-	40	KS M ISO 6326-1, KS M ISO 19739, ASTM D5504, JIS K 0127
Inert gas(CO_2, N_2 ,etc.)	vol%	-	4.5	KS M ISO 6974, ASTM D1946, ASTM D1945-81, JIS K 0114

4.2.3. "G25""Low Gas" (nominal 86 % Methane)

Table A3/11
"G25" "Low Gas" (nominal 86 per cent Methane)

Characteristics	*Units*	*Basis*	*Limits*		*Test method*
			Minimum	*Maximum*	
Composition:					
Methane	% mole	86	84	88	ISO 6974
Balance [1]	% mole	—	—	1	ISO 6974
N_2	% mole	14	12	16	ISO 6974
Sulphur content	$mg/m^{3(2)}$	—	—	10	ISO 6326-5
Wobbe Index (net)	$MJ/m^{3(3)}$	39.4	38.2	40.6	

(1) Inerts (different from N_2) + C2 + C2+.
(2) Value to be determined at 293.15 K (20 °C) and 101.325 kPa.
(3) Value to be determined at 273.15 K (0 °C) and 101.325 kPa.

4.2.4. "J-Gas" (nominal 85 % Methane)

Table A3/12
"J-Gas" (nominal 85 per cent Methane)

Characteristics	Units	Limits	
		Minimum	Maximum
Methane	% mole	85	
Ethane	% mole		10
Propane	% mole		6
Butane	% mole		4
HC of C_3+C_4	% mole		8
HC of C_5 or more	% mole		0.1
Other gases (H_2+O_2+N_2+CO+CO_2)	% mole		1.0
Sulphur content	mg/Nm^3		10
Wobbe Index	WI	13.260	13.730
Gross Calorific value	$kcal/Nm^3$	10.410	11.050
Maximum combustion speed	MCP	36.8	37.5

5. Liquid fuels for compression ignition engines

5.1. J-Diesel (nominal 53 Cetane, B0)

Table A3/13
J-Diesel (nominal 53 Cetane, B0)

Fuel Property or Substance Name	Units	Specification		Test method
		Minimum	Maximum	
Cetane number		53	57	JIS K2280
Density	g/cm³	0.824	0.840	JIS K2249
Distillation:				
— 50 % distillation temperature	K (°C)	528 (255)	568 (295)	JIS K2254
— 90 % distillation temperature	K (°C)	573 (300)	618 (345)	JIS K2254
— final boiling point	K (°C)		643 (370)	JIS K2254
Flash point	K (°C)	331(58)		JIS K2265–3
Kinematic Viscosity at 30 °C	mm^2/s	3.0	4.5	JIS K2283
All aromatic series	vol %		25	JIS Method HPLC
Polycyclic aromatic hydrocarbons	vol %		5.0	JIS Method HPLC
Sulphur content	Wt ppm		10	JIS K2541-1 JIS K2541-2 JIS K2541-6 JIS K2541-7
FAME	%		0.1	Method prescribed in the Japanese concentration measurement procedure announcement
Triglyceride	%		0.01	Method prescribed in the Japanese concentration measurement procedure announcement

5.2. E-Diesel (nominal 52 Cetane, B5)

Table A3/14
E-Diesel (nominal 52 Cetane, B5)

Parameter	Unit	Limits [1]		Test method
		Minimum	Maximum	
Cetane number [2]		52.0	54.0	EN-ISO 5165
Density at 15 °C	kg/m^3	833	837	EN-ISO 3675
Distillation:				
— 50 % point	°C	245	—	EN-ISO 3405
— 95 % point	°C	345	350	EN-ISO 3405
— final boiling point	°C	—	370	EN-ISO 3405
Flash point	°C	55	—	EN 22719
CFPP	°C	—	–5	EN 116
Viscosity at 40 °C	mm^2/s	2.3	3.3	EN-ISO 3104
Polycyclic aromatic hydrocarbons	% m/m	2.0	6.0	EN 12916
Sulphur content [3]	mg/kg	—	10	EN ISO 20846/ EN ISO 20884
Copper corrosion		—	Class 1	EN-ISO 2160
Conradson carbon residue (10 % DR)	% m/m	—	0.2	EN-ISO10370
Ash content	% m/m	—	0.01	EN-ISO 6245
Water content	% m/m	—	0.02	EN-ISO12937
Neutralization (strong acid) number	mg KOH/g	—	0.02	ASTM D 974
Oxidation stability [4]	mg/ml	—	0.025	EN-ISO12205
Lubricity (HFRR wear scan diameter at 60 °C)	µm	—	400	EN ISO 12156
Oxidation stability at 110 °C [4][6]	h	20.0		EN 14112
FAME [5]	% v/v	4.5	5.5	EN 14078

[1] The values quoted in the specifications are 'true values'. In establishing of their limit values the terms of ISO 4259 Petroleum products — Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

[2] The range for cetane number is not in accordance with the requirements of a minimum range of 4R. However, in the case of a dispute between fuel supplier and fuel user, the terms of ISO 4259 may be used to resolve such disputes provided replicate measurements, of sufficient number to archive the necessary precision, are made in preference to single determinations.

[3] The actual sulphur content of the fuel used for the Type 1 test shall be recorded.

[4] Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice shall be sought from the supplier as to storage conditions and life.

[5] FAME content to meet the specification of EN 14214.

[6] Oxidation stability can be demonstrated by EN-ISO12205 or by EN 14112. This requirement shall be reviewed based on CEN/TC19 evaluations of oxidative stability performance and test limits.

5.3. K-Diesel (nominal 52 Cetane, B5)

Table A3/15
K-Diesel (nominal 52 Cetane, B5)

Fuel Property or Substance Name	Units	Specification		Test method
		Minimum	Maximum	
Pour point	℃	-	0.0 (winter: -17.5℃)	ASTM D6749
Flash point	℃	40	-	KS M ISO 2719
Kinematic Viscosity at 40 ℃	mm^2/s	1.9	5.5	KS M 2014
90% distillation temperature	℃	-	360	ASTM D86
10% carbon residue	wt%	-	0.15	KS M 2017, ISO 4262, IP 14, ASTM D524
Water content	vol%	-	0.02	KS M 2115
Sulphur content	mg/kg	-	10	KS M 2027, ASTM D5453
Ash	wt%	-	0.02	KS M ISO 6245
Cetane number		52	-	KS M 2610,
Copper corrosion	100℃, 3h	-	1	KS M 2018
Lubricity(60℃, micron)(HFRR)		-	400	CFC F-06-A, ASTM D6079
Density(15℃)	kg/cm^3	815	835	KS M 2002, ASTM D4052
Polycyclic aromatic hydrocarbons	wt%	-	5	KS M 2456
All aromatic series	wt%	-	30	IP 391, ASTM D5186
Fatty acid methyl esters content	vol%	-	5	EN 14078

5.4. E-Diesel (nominal 52 Cetane, B7)

Table A3/16
E-Diesel (nominal 52 Cetane, B7)

Parameter	Unit	Limits [1]		Test method
		Minimum	Maximum	
Cetane Index		46.0		EN-ISO 4264
Cetane number [2]		52.0	56.0	EN-ISO 5165
Density at 15 °C	kg/m^3	833.0	837.0	EN-ISO 12185
Distillation:				
— 50 % point	°C	245.0	—	EN-ISO 3405
— 95 % point	°C	345.0	360.0	EN-ISO 3405
— final boiling point	°C	—	370.0	EN-ISO 3405
Flash point	°C	55	—	EN ISO 2719
Cloud point	°C	—	-10	EN 116
Viscosity at 40 °C	mm^2/s	2.30	3.30	EN-ISO 3104
Polycyclic aromatic hydrocarbons	% m/m	2.0	4.0	EN 12916
Sulphur content	mg/kg	—	10.0	EN ISO 20846/ EN ISO 20884
Copper corrosion (3 hours, 50 °C)		—	Class 1	EN-ISO 2160
Conradson carbon residue (10 % DR)	% m/m	—	0.20	EN-ISO10370
Ash content	% m/m	—	0.010	EN-ISO 6245
Total contamination	mg/kg		24	EN 12662
Water content	mg/kg	—	200	EN-ISO12937
Acid number	mg KOH/g	—	0.10	EN ISO 6618
Lubricity (HFRR wear scan diameter at 60 °C)	µm	—	400	EN ISO 12156
Oxidation stability at 110 °C [3]	h	20.0		EN 15751
FAME [4]	% v/v	6.0	7.0	EN 14078

[1] The values quoted in the specifications are 'true values'. In establishing of their limit values the terms of ISO 4259 Petroleum products – Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).
Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.

[2] The range for cetane number is not in accordance with the requirements of a minimum range of 4R. However, in the case of a dispute between fuel supplier and fuel user, the terms of ISO 4259 may be used to resolve such disputes provided replicate measurements, of sufficient number to archive the necessary precision, are made in preference to single determinations.

[3] Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice shall be sought from the supplier as to storage conditions and life.

[4] FAME content to meet the specification of EN 14214.

Annex 4

Road load and dynamometer setting

1. Scope

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

2. Terms and definitions

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

2.2. Reference speed points shall start at 20 km/h in incremental steps of 10 km/h and with the highest reference speed according to the following provisions:

(a) The highest reference speed point shall be 130 km/h or the reference speed point immediately above the maximum speed of the applicable test cycle if this value is less than 130 km/h. In the case that the applicable test cycle contains less than the 4 cycle phases (Low, Medium, High and Extra High) and on the request of the manufacturer, the highest reference speed may be increased to the reference speed point immediately above the maximum speed of the next higher phase, but no higher than 130 km/h; in this case road load determination and chassis dynamometer setting shall be done with the same reference speed points.

(b) If a reference speed point applicable for the cycle plus 14 km/h is more than or equal to the maximum vehicle speed, v_{max}, this reference speed point shall be excluded from the coast down test and from chassis dynamometer setting. The next lower reference speed point shall become the highest reference speed point for the vehicle.

2.3. Unless otherwise specified, a cycle energy demand shall be calculated according to paragraph 5 of Annex 7 over the target speed trace of the applicable drive cycle.

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

(k) 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.

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

3.2.1. Wind velocity

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

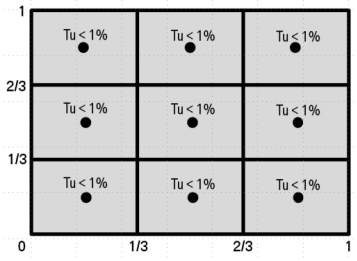
3.2.2. Air temperature

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

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



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

where:

Tu is turbulence intensity;

u' is turbulent velocity fluctuation, m/s;

U_∞ is free flow velocity, m/s.

3.2.4. Solid blockage ratio

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

$$\varepsilon_{sb} = \frac{A_f}{A_{nozzle}} \times 100 \qquad (2)$$

where:

ε_{sb} is vehicle blockage ratio, per cent;

A_f is frontal area of the vehicle, m²;

A_{nozzle} is the nozzle outlet area, 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

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 the nozzle outlet

At nine equally distributed points over the nozzle area, the standard deviation of the total pressure at the nozzle outlet shall be equal to or less than 2 per cent.

$$\sigma \left(\frac{\Delta P_t}{q}\right) \leq 2\ \%$$

where:

σ is the standard deviation of the pressure ratio $\left(\frac{\Delta P_t}{q}\right)$;

ΔP_t is the variation of total pressure between the measurement points, N/m^2;

q is the dynamic pressure, N/ m².

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

$$|cp_{x=+2m} - cp_{x=-2m}| \leq 1 \text{ per cent} \qquad (3)$$

where:

cp is the pressure coefficient.

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.

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

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 blockage ratio

The restraint system mounting shall not be in front of the vehicle. The relative blockage ratio of the vehicle frontal area due to the restraint system, $\varepsilon_{\mathrm{restr}}$, shall not exceed 10 per cent.

$$\varepsilon_{\mathrm{restr}} = \frac{A_{\mathrm{restr}}}{A_f} \times 100 \qquad (4)$$

where:

$\varepsilon_{\mathrm{restr}}$ is the relative blockage ratio of the restraint system, per cent;

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

A_f is the frontal area of the vehicle, 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 type of anemometry 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 a 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. Any wind correction shall be calculated as given in paragraph 4.5.3. 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 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.

Contracting Parties may choose to permit more lenient 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.

4.1.1.2. Atmospheric temperature

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

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

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

4.1.2. Test road

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 metres 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

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 recorded.

4.2.1.1. Without using the interpolation method

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

If the aerodynamic influence of the different wheel rims within one interpolation family is not known, the selection shall be based on the highest expected aerodynamic drag. 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).

The wheel selection shall be executed without prejudice of the requirement of the highest cycle energy demand.

4.2.1.2. Using the interpolation method

At the request of the manufacturer, the interpolation method may be applied for individual vehicles in the interpolation family (see paragraph 1.2.3.1. of Annex 6 and paragraph 3.2.3.2. of Annex 7).

In this case, two test vehicles shall be selected from the interpolation family complying with the requirements of the interpolation method (paragraphs 1.2.3.1. and 1.2.3.2. of Annex 6).

Test vehicle H shall be the vehicle producing the higher, and preferably highest, cycle energy demand of that selection, test vehicle L the one producing the lower, and preferably lowest, cycle energy demand of that selection.

All options and/or body shapes that are not to be considered in the interpolation method, should be applied to both test vehicles H and L such that they produce the highest combination of the cycle energy demand of their road load relevant characteristics (i.e. mass, aerodynamic drag and tyre rolling resistance).

4.2.1.3. [RESERVED: Road load family]

4.2.1.4. 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.).

Every vehicle system that dynamically modifies the vehicle's aerodynamic drag (e.g. vehicle height control) shall be considered to be a movable aerodynamic body part. 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.

4.2.1.5. 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 test mass of vehicle H or of vehicle L at the start of the road load determination procedure.

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

4.2.1.6. Test vehicle configuration

The test vehicle configuration shall be recorded and shall be used for any subsequent testing.

4.2.1.7. Test vehicle condition

4.2.1.7.1. 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.

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

4.2.1.7.2. Manufacturer's specifications

The vehicle shall conform to the manufacturer's intended production vehicle specifications regarding tyre pressures described in paragraph 4.2.2.3., wheel alignment described in paragraph 4.2.1.5.3., ground clearance, vehicle height, drivetrain and wheel bearing lubricants, and brake adjustment to avoid unrepresentative parasitic drag.

4.2.1.7.3. Wheel alignment

Toe and camber shall be set to the maximum deviation from the longitudinal axis of the vehicle in the range defined by the manufacturer. If a manufacturer prescribes values for toe and camber for the vehicle, these values shall be used. At the request of the manufacturer, values with higher deviations from the longitudinal axis of the vehicle than the prescribed values may be used. The prescribed values shall be the reference for all maintenance during the lifetime of the car.

Other adjustable wheel alignment parameters (such as caster) shall be set to the values recommended by the manufacturer. In the absence of recommended values, they shall be set to the mean value of the range defined by the manufacturer.

Such adjustable parameters and set values shall be recorded.

4.2.1.7.4. Closed panels

During the road load determination, the engine bonnet, manually-operated movable panels and all windows shall be closed.

4.2.1.7.5. Coastdown mode

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

4.2.1.7.5.1. 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 Annex 6 of 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.

Table A4/1
Classes of Rolling Resistance Coefficients (RRC) for Tyre Categories C1, C2 and C3, kg/tonne

Class	C1 range	C2 range	C3 range
1	RRC ≤ 6.5	RRC ≤ 5.5	RRC ≤ 4.0
2	6.5 < RRC ≤ 7.7	5.5 < RRC ≤ 6.7	4.0 < RRC ≤ 5.0
3	7.7 < RRC ≤ 9.0	6.7 < RRC ≤ 8.0	5.0 < RRC ≤ 6.0
4	9.0 < RRC ≤ 10.5	8.0 < RRC ≤ 9.2	6.0 < RRC ≤ 7.0
5	10.5 < RRC ≤ 12.0	9.2 < RRC ≤ 10.5	7.0 < RRC ≤ 8.0
6	RRC > 12.0	RRC > 10.5	RRC > 8.0
Class	C1 class value	C2 class value	C3 class value
1	RRC = 5.9	RRC = 4.9	RRC = 3.5
2	RRC = 7.1	RRC = 6.1	RRC = 4.5
3	RRC = 8.4	RRC = 7.4	RRC = 5.5
4	RRC = 9.8	RRC = 8.6	RRC = 6.5
5	RRC = 11.3	RRC = 9.9	RRC = 7.5
6	RRC = 12.9	RRC = 11.2	RRC = 8.5

The actual rolling resistance 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 interpolation family, the CO_2 interpolation method shall be based on the RRC class value for the tyres fitted to an individual vehicle.

4.2.2.2. Tyre condition

Tyres used for the test shall:

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

(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 at any point 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:

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

where:

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

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.

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 Annex. The vehicle shall be warmed up for at least 20 minutes until stable conditions are reached.

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

Vehicle class	Applicable WLTC	90 per cent of maximum speed	Next higher phase
	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

Refer to paragraph 4.3.1.4.2. of this Annex.

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

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

4.3.1. Coastdown method with stationary anemometry

4.3.1.1. Selection of reference speeds for road load curve determination

Reference speeds for road load determination shall be selected according to paragraph 2. of this Annex.

4.3.1.2. Data collection

During the test, elapsed time and vehicle speed shall be measured and recorded at a minimum frequency 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 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 10 km/h above the highest reference speed 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. .

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 all the reference speed points. 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 ($v_j + 5$ km/h) to ($v_j - 5$ km/h) shall be measured.

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_j, in per cent, defined below.

$$p_j = \frac{h \times \sigma_j}{\sqrt{n}} \times \frac{100}{\Delta t_{pj}} \leq 3\ \% \quad (6)$$

where:

p_j is the statistical accuracy of the measurements made at reference speed v_j;

n is the number of pairs of measurements;

Δt_{pj} is the mean coastdown time at reference speed v_j in seconds, given by the equation:

$$\Delta t_{pj} = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{ji} \quad (7)$$

where $\Delta t_{ji}$is the harmonized average coastdown time of the i^{th} pair of measurements at velocity v_j, seconds (s), given by the equation:

$$\Delta t_{ji} = \frac{2}{\left(\frac{1}{\Delta t_{jai}}\right) + \left(\frac{1}{\Delta t_{jbi}}\right)} \quad (8)$$

where:

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

σ_j is the standard deviation, expressed in seconds (s), defined by:

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta t_{ji} - \Delta t_{pj})^2} \quad (9)$$

h is a coefficient given in Table A4/3.

Table A4/3
Coefficient h as Function of n

n	h	$h/\sqrt{n}$	n	h	$h/\sqrt{n}$
3	4.3	2.48	10	2.2	0.73
4	3.2	1.60	11	2.2	0.66
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_j in directions a and b, , 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, N;

F_{jb} is the total resistance at reference speed, j, in direction b, 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 responsible 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 interpolation family;

Δt_{ja} and Δt_{jb} are the mean coastdown times in directions a and b, respectively, corresponding to reference speed v_j, in seconds (s), given by the following equations:

$$\Delta t_{ja} = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{jai} \quad (12)$$

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

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_j, seconds (s), given by:

$$\Delta t_j = \frac{2}{\frac{1}{\Delta t_{ja}} + \frac{1}{\Delta t_{jb}}} \quad (15)$$

where Δt_{ja} and Δt_{jb} are the coastdown times at velocity v_j, 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 interpolation 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. Coastdown method with on-board anemometry

The vehicle shall be warmed up and stabilised according to paragraph 4.2.4. of this Annex. Calibration of instrumentation shall 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 frequency 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. The 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 shall be selected according to paragraph 2 of this Annex.

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 a frequency of 5 Hz. Ambient temperature shall be synchronised and sampled at a minimum frequency of 1 Hz.

4.3.2.4. Vehicle coastdown procedure

Vehicle coastdowns 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 with five runs being performed in each direction. Wind-corrected coastdown data shall satisfy the statistical accuracy 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 metres 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.

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 aerodynamic 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
A_m	N	coefficient of mechanical drag
B_m	N/(km/h)	coefficient of mechanical drag
C_m	$N/(km/h)^2$	coefficient of mechanical drag
$C_d(Y)$		coefficient of aerodynamic drag at yaw angle Y
D	N	drag
D_{aero}	N	aerodynamic drag
D_f	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_{tyre}	N	tyre rolling resistance
(dv/dt)	m/s^2	acceleration
g	m/s^2	gravitational constant
m	kg	mass of vehicle
m_e	kg	effective vehicle mass (including rotating components)
ρ	kg/m^3	air density
t	s	Time
T	K	Temperature
v	km/h	vehicle speed
v_r	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:

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

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

m_e is the effective vehicle mass, kg.

4.3.2.5.2. Mechanical drag modelling

Mechanical drag consisting of separate components representing tyre, D_{tyre}, and front and rear axle frictional losses, D_f and D_r, including transmission losses) can be modelled as a three-term polynomial as a function of 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 as a function of yaw angle, 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;

Y is the yaw angle, degrees.

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:

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

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

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

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

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

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 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 $\left(head_i - head_{i+1}\right)^2$, 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.

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 a frequency of 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 givenM_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.

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.

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 Annex.

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 for time periods of at least5 seconds.

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. Start of data collection

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

The reference speeds shall be measured in descending order. At 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.

4.4.2.2. 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 shall be referred to as one measurement.

4.4.2.3. Velocity deviation

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

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 paragraph4.4.2.2. 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:

$$C_{js} = (m_{av} + m_r) \times \alpha_j r_j. \quad (26)$$

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/s^2;

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, 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, s^{-1};

α_j is the mean acceleration, m/s^2, which shall be calculated by the equation

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

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:

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

where:

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

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

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

where:

C_{jmi} is the average torque of the i^{th} pair of measurements at speed v_j, Nm and given by:

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

where:

C_{jmai} and C_{jmbi} are the mean torques of the i^{th} 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, Nm, defined by the equation

$$s = \sqrt{\frac{1}{k-1}\sum_{i=1}^{k}\left(C_{jmi} - \overline{C_j}\right)^2}; \quad (32)$$

h 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, $\overline{v_j}$, by more than ± 1 km/h or 2 per cent of the average speed, v_{jmi}, whichever is greater. The values of $\overline{v_j}$ and v_{jmi} shall be calculated as follows:

$$\overline{v_j} = \frac{1}{n}\sum_{i=1}^{n} v_{jmi} \quad (33)$$

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

where:

v_{jmai} and v_{jmbi} are the mean speeds of the i^{th} 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}:

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

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

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 is calculated by the following equation:

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

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

$$c_0 = \frac{c_{0a}+c_{0b}}{2} \quad (38)$$

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

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

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.

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 Annex) shall be recorded.

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, 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 responsible authority for the particular vehicle and tyre test, or may be assumed to be as follows:

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

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 Annex;

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 for the torque meter method determined in paragraph 4.4.4. of this Annex.

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:

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

where:

f_0 is a constant term, N;

TM_H is the 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 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:

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

where:

f_0 is a constant term, N;

TM_L is the 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 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 Annex shall be corrected to reference conditions as follows and shall be used as the target coefficients in paragraph 8.1.1.:

$$F^* = \left((f_0 - w_1 - K_1) + f_1 v\right) \times \left(1 + K_0(T - 20)\right) + K_2 f_2 v^2 \quad (45)$$

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 Annex;

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

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

T is the mean atmospheric temperature, °C;

v is vehicle velocity, km/h;

w_1 is the wind resistance correction as defined in paragraph 4.5.3. of this Annex, N.

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

$$C^* = \left((c_0 - w_2 - K_1) + c_1 v\right) \times \left(1 + K_0(T - 20)\right) + K_2 c_2 \rho v^2 \quad (46)$$

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 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 Annex;

v is the vehicle velocity, km/h;

T is the mean atmospheric temperature, °C;

ρ is the mean air density, kg/m³;

w_2 is the wind correction resistance as defined in paragraph 4.5.3. of this 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, several parameters such as test mass, width and height of the vehicle shall be used. The default road load, F_c, shall be calculated for the reference speed points..

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 as a function of vehicle velocity, N;

f_0 is the constant road load coefficient, N, defined by the equation:

$$f_0 = 0.140 \times TM; \quad (48)$$

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

f_2 is the second order road load coefficient, N·(h/km)², defined by the equation:

$f_2 = (2.8 \times 10^{-6} \times TM) + (0.0170 \times width \times height);$(49)

v is vehicle velocity, km/h;

TM test mass, kg;

width vehicle width, metres, as defined in 6.2. of Standard ISO 612:1978;

height vehicle height, metres, as defined in 6.3. of Standard ISO 612:1978.

6. Wind tunnel method

The wind tunnel method is a road load measurement method using a combination of a wind tunnel and a roller chassis dynamometer or of a wind tunnel and a flat belt dynamometer. The test benches may be separate facilities or integrated with one another.

6.1. Description of the measurement method

Comment [SMD56]: EXPERT PROPOSAL: 02.04.2015. Currently being developed.

Comment [SMD57]: EXPERT PROPOSAL: April 2015 drafting meeting, Stockholm. This is version WLTP-10-16e

6.1.1. The total road load shall be determined by:

(a) adding the road load forces measured in a wind tunnel and those measured using a flat belt, or,

(b) adding the road load forces measured in a wind tunnel and those measured on a chassis dynamometer.

6.1.2. The aerodynamic drag shall be measured in the wind tunnel.

6.1.3. Rolling resistance and drivetrain losses shall be measured using a flat belt or a chassis dynamometer.

6.1.4. Fulfilling the requirements of both, flat belt and wind tunnel, with one test bench at the same time are also qualified.

6.2. Approval of facilities by the responsible authority

The results of the wind tunnel method shall be compared to those obtained using the coastdown method to demonstrate qualification of the facilities .

6.2.1. Three vehicles shall be selected by the responsible authority. These vehicles should cover the range of vehicles (e.g. size, weight) planned to be measured with the facilities concerned.

6.2.2. Two separate coastdown tests shall be performed with each of the three vehicles according to paragraph 4.3. of this Annex, and the resulting road load coefficients f_0, f_1 and f_2 shall be determined according to that paragraph and corrected according to paragraph 4.5.5. The coastdown result of a test vehicle shall be the average of its two separate coastdowns.

6.2.3. Measurement with the wind tunnel method according to the following paragraphs shall be performed on the same three vehicles in the same conditions, and the resulting road load coefficients f_0, f_1 and f_2 shall be determined. If the alternative preconditioning in paragraph 6.5.2.1. is used, it shall also be used for the approval of the facilities.

6.2.4. Approval criteria

The facility or combination of facilities used shall be approved if the following two criteria are met:

(a) The difference in cycle energy, expressed as ε_k, between the wind tunnel method and the coast down method shall be within ± [5] per cent for each of the three vehicles, k, according to the following equation:

$$\varepsilon_k = \frac{E_{k,WTM}}{E_{k,coastdown}} - 1 \qquad \text{(XX)}$$

where:

ε_k is the difference in cycle energy for vehicle k between the wind tunnel method and the coast down method, per cent;

Comment [SMD58]: GTR CORRECTION: 01.05.2015: Is the text "according to the following paragraphs" necessary?

Comment [SMD59]: OPEN POINT: April 2015 drafting meeting, Stockholm should this not refer directly to the references in 6.5.2.1.?

$E_{k,WTM}$ is the cycle energy for vehicle k calculated with the road load derived from the wind tunnel method according to paragraph 5 of Annex 7, J;

$E_{k,coast\ down}$ is the cycle energy for vehicle k calculated with the road load derived from the coast down method, calculated according to paragraph 5 of Annex 7, J.;

(b) The average, $\overline{X}$, of the three differences shall be within [2] per cent.

$$\overline{X} = \left| \frac{\varepsilon_1 + \varepsilon_2 + \varepsilon_3}{3} \right| \qquad \text{(XX)}$$

Comment [SMD60]: EXPERT PROPOSAL: 28.03.2015. Clarify if 2 % or 3 %.

The facility may be used for road load determination for a maximum of [two] years after the approval has been granted.

Each combination of chassis dynamometer or moving belt and wind tunnel shall be approved separately.

6.3. Vehicle preparation and temperature

The vehicle condition as well as its preparation shall be according to paragraphs 4.2.1. and 4.2.2. of this Annex and applies to both the flat belt or roller chassis dynamometer methods, and the wind tunnel measurements.

The test cell of the flat belt or the roller chassis dynamometer test cells shall have a temperature set point of 20 °C with a tolerance of ± 3 °C. At the request of the manufacturer, the set point may also be 23 °C with a tolerance of ± 3 °C .

6.4. Wind tunnel procedure

6.4.1. Wind tunnel criteria

The wind tunnel design, test methods and the corrections shall provide a value with an accuracy of 0.015 m² of $C_d \times A_f$ representative of the on-road $C_d \times A_f$ value.

For all $C_d \times A_f$ measurements, the wind tunnel criteria listed in paragraph 3.2. of this Annex shall be met with the following modifications-:

(a) The solid blockage ratio described in paragraph 3.2.4. of this Annex shall be below [25] per cent,

(b) The belt surface contacting any tyre shall exceed the length of that tyre's contact area by at least 20 per cent and shall be at least as wide as that contact patch area,

(c) The standard deviation of total air pressure at the nozzle outlet described in paragraph 3.2.8. of this Annex shall be below 0.5 per cent.

(d) The restraint system blockage ratio described in paragraph 3.2.10. of this Annex shall be below [3] per cent.

6.4.2. Wind tunnel measurement

The vehicle shall be in the condition described in paragraph 6.3 of this Annex.

The vehicle shall be placed parallel to the longitudinal centre line of the tunnel with a maximum deviation of [10] mm.

The vehicle shall be placed with 0° yaw angle with a tolerance of ± 0.1°.

The aerodynamic drag shall be measured at least for [60] seconds and at a minimum frequency of [5] Hz. The result shall be the average of the measured drag during the measurement.

If the vehicle has movable aerodynamic body parts, paragraph 4.2.1.4. of this Annex shall apply. In the case where movable parts are velocity-dependent, every applicable position shall be measured in the wind tunnel and evidence shall be given to the responsible authority indicating the relationship between (a) reference speed, (b) movable part position, and (c) the corresponding Cd × Af.

6.5. Flat belt method

6.5.1. Flat belt criteria

6.5.1.1. Layout of a flat belt test bench

The wheels shall rotate on flat belts which do not change the rolling characteristics of the wheels compared to that on the road. The measured forces in the x-direction shall include the frictional forces in the drivetrain .

6.5.1.2. Vehicle restraint system

The dynamometer shall be equipped with a centring device which aligns the vehicle within a tolerance of ± 0.5 degrees to the longitudinal centre line of the test bed. The restraint system shall maintain the centred drive wheel position within the following recommended limits throughout the coastdown runs of the road load determination.

6.5.1.2.1. Lateral position (y axis)

The vehicle shall remain aligned in the y-direction and lateral movement shall be minimized.

6.5.1.2.2. Front and rear position (x axis)

Without prejudice to the requirement of paragraph 6.5.1.2.1. , both wheel axes shall be within ± 10 mm of the belt's lateral centrelines.

6.5.1.2.3. Vertical force

The restraint system shall be designed so as to impose no vertical force on the drive wheels.

Comment [SMD61]: OPEN POINT: April 2015 drafting meeting, Stockholm: are these really limits? How to encompass 6.5.1.2.1., 6.5.2.1.2.2. and 6.5.1.2.3.?

Comment [SMD62]: GTR CORRECTION: 01.05.2015. Proposal: The restraint system shall maintain the centred drive wheel position by fulfilling the requirements of paragraphs 6.5.1.2.1. to 6.5.1.2.3. inclusive throughout the coastdown runs of the road load determination.

6.5.1.3. Accuracy of measured forces

Only the reaction force for turning the wheels shall be measured. No external forces shall be included in the result (e.g. air force of the cooling fan, vehicle restraints, aerodynamic reaction forces of the flat belt, etc.).

The force in the x-direction shall be measured with an accuracy of ± 5 N.

6.5.1.4. Flat belt speed control

The belt speed shall be controlled with an accuracy of ± 0.1 km/h.

6.5.1.5. Flat belt surface

The flat belt surface shall be clean, dry and free from foreign material which might cause tyre slippage.

6.5.1.6. Cooling

A current of air of variable speed shall be blown towards the vehicle. At measurement speeds above 5 km/h, the set point of the linear velocity of the air at the blower outlet shall be equal to the corresponding roller speed. 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 measurement speed, whichever is greater.

Comment [SMD63]: GTR CORRECTION: April 2015 drafting meeting, Stockholm. Rewritten

6.5.2. Flat belt measurement

6.5.2.1. Preconditioning

The vehicle shall be conditioned as described in paragraphs 4.2.4.1.1. to 4.2.4.1.3. of this Annex by driving the vehicle under its own power.

At the request of the manufacturer, as an alternative to paragraph 4.2.4.1.2, the warm-up may be conducted by driving the vehicle with the flat belt, but only if this warm-up method was used during approval of the facility.

In this case, the warm-up speed shall be 110 per cent of the maximum speed of the applicable WLTC and the duration shall exceed 1200 seconds until the change of measured force over a period of 200 seconds is smaller than 5 N.

Comment [SMD64]: GTR CORRECTION: OPEN POINT: April 2015 drafting meeting, Stockholm. Should these 2 paragraphs be merged to clarify what is meant by “in this case”.

6.5.2.2. Measurement procedure

6.5.2.2.1. The test shall be conducted from the highest to the lowest reference speed point.

6.5.2.2.2. Brake conditioning and warm-up shall be performed according to paragraphs 4.2.4.1.1. to 4.2.4.1.3. inclusive of this Annex.

6.5.2.2.3. The deceleration from the current to the next applicable reference speed point shall be done in a smooth transition from approximately 1 m/s².

6.5.2.2.4. The reference speed shall be stabilised for at least [4] seconds;

6.5.2.2.5. The average force at each reference speed shall be measured for at least [6] seconds while the vehicle speed is kept constant. The resulting force for that reference speed point shall be the average of the recorded force during the measurement.

Comment [SMD65]: OPEN POINT: April 2015 drafting meeting, Stockholm. Is the second sentence redundant? It basically says the same as the first.

The steps in paragraphs 6.5.2.2.3. to 6.5.2.2.5. inclusive shall be repeated for each reference speed.

6.5.2.3. Measurement conditions

During measurement, the transmission shall be in a neutral position, 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.

6.6. Chassis dynamometer

[Reserved]

6.7. Calculations

6.7.1. Correction of flat belt and chassis dynamometer result

The measured forces determined in paragraphs 6.5. and 6.6. of this Annex shall be corrected to reference conditions as follows:

$$F_Dj = (f_j - K_1) \times (1 + K_0 (T - 293\ K)) \quad (XX)$$

where:

F_Dj is the corrected total resistance measured at the flat belt or chassis dynamometero at reference speed j N;

f_j is the measured force at reference speed j, N;

K_0 is the correction factor for rolling resistance as defined in paragraph 4.5.2.of this Annex, K-1;

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

T is the mean temperature in the test cell during the measurement, Kelvin.

6.7.2. Calculation of the aerodynamic force

The aerodynamic drag shall be calculated as follows. If the vehicle is equipped with velocity- dependent movable aerodynamic body parts, the corresponding Cd × Af values shall be applied for the concerned reference speed points.

$$F_Aj = (C_d * A_f)_j * \rho_0 / 2 * (v_j^2) / [[3.6]]^2 \quad (XX)$$

where:

F_A is the aerodynamic drag measured in the wind tunnel, N;

(C_d* A_f)_j is the measured aerodynamic drag, if applicable at a certain reference speed point j, m²;

ρ_0 is the dry air density defined in paragraph 3.2.9. of this gtr, kg/m³;

v_j is the reference speed j, km/h.

6.7.3. Calculation of road load values

The following equation shall be used to calculate the total road load as a sum of the results of paragraphs 6.7.1 and 6.7.2. of this Annex.

F_j^*= F_Dj + F_Aj for all applicable reference speed points j, N; (XX)

With all calculated F_j^* the coefficients f_0, f_1 and f_2 in the total resistance equation shall be calculated with a least squares regression analysis and shall be used as the target coefficients in paragraph 8.1.1.

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(s)

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 recorded.

7.1.1.2. Room temperature

The laboratory atmospheric temperature shall be at a set point of 296 K (23 °C) and shall not deviate by more than ± 5 K (± 5 °C) 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 if a dual-axis chassis dynamometer is used. In the case that a single-axis chassis dynamometer is used, the equivalent inertia mass shall be increased by 1.5 per cent. 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 Annex), and shall be recorded.

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

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 placed on the chassis dynamometer 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 paragraph4.2.4.1.2. of this 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 + $Medium_2$ + $High_2$ + Extra $High_2$
	Low_2 + $Medium_2$ + $High_2$	Yes (Extra $High_2$)	
		No	Low_2 + $Medium_2$ + $High_2$
Class 3	Low_3 + $Medium_3$ + $High_3$ + Extra $High_3$	Low_3 + $Medium_3$ + $High_3$ + Extra $High_3$	Low_3 + $Medium_3$ + $High_3$ + Extra $High_3$
	Low_3 + $Medium_3$ + $High_3$	Yes (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.

7.3.4.3. Alternative warm-up procedure

7.3.4.3.1. At the request of the vehicle manufacturer and approval of the responsible authority, an alternative warm-up procedure may be used. The approved alternative warm-up procedure may be used for vehicles within the same road load family and shall satisfy the requirements outlined in paragraphs 7.3.4.3.2. to 7.3.4.3.5. inclusive.

7.3.4.3.2. At least one vehicle representing the road load family shall be selected.

7.3.4.3.3. The cycle energy demand calculated according to paragraph 5 of Annex 7 with corrected road load parameters, f_{0a}, f_{1a} and f_{2a}, for the alternative warm-up procedure shall be equal to or higher than the cycle energy demand calculated with the target road load parameters, f_0, f_1, and f_2, for each applicable phase.

The corrected road load parameters, f_{0a}, f_{1a} and f_{2a}, shall be calculated according to the following equations:

$$f_{0a} = f_0 + A_{d_alt} - A_{d_WLTC} \quad \text{(XX)}$$

$$f_{1a} = f_1 + B_{d_alt} - B_{d_WLTC} \quad \text{(YY)}$$

$$f_{2a} = f_2 + C_{d_alt} - C_{d_WLTC} \quad \text{(ZZ)}$$

where:

A_{d_alt}, B_{d_alt} and C_{d_alt} are the chassis dynamometer setting coefficients after the alternative warm-up procedure;

A_{d_WLTC}, B_{d_WLTC} and C_{d_WLTC} are the chassis dynamometer setting coefficients after a WLTC warm-up procedure described in paragraph 7.3.4.1. of this Annex.

7.3.4.3.4. The corrected road load parameters, f_{0a}, f_{1a} and f_{2a}, shall be used only for the purpose of paragraph 7.3.4.3.3. of this Annex. For other purposes, the target road load parameters, f_0, f_1 and f_2, shall be used as the target road load parameters.

7.3.4.3.5. Details of the procedure and of its equivalency shall be provided to the responsible authority.

Comment [SMD66]: GTR CORRECTION: 20.01.2015: Changed from "reported".

8. Chassis dynamometer load setting

8.1. Chassis dynamometer setting by the coastdown method

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

8.1.1. Initial load setting

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

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

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

for single-axis chassis dynamometers, or

$A_d = 0.1 \times A_t, B_d = 0.2 \times B_t, C_d = C_t$ (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 Annex.

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 m^2/sec^3.

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 Annex. Paragraphs 8.1.2. and 8.1.3. above shall be repeated.

8.2. Chassis dynamometer load setting using the 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 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)

for single-axis chassis dynamometers, or

$$A_d = 0.1 \times \frac{a_t}{r'}, B_d = 0.2 \times \frac{b_t}{r'}, C_d = \frac{c_t}{r'} \quad (56)$$

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, metres, obtained by averaging the r'_j values calculated in paragraph 2.1. of Appendix 1 to this 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.

$$F_{tj} = \frac{a_t + b_t \times v_j + c_t \times v_j^2}{r'} \quad (57)$$

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, metres, obtained by averaging the r'_j values calculated according to paragraph 2.1. in Appendix 1 to this 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 Appendix 1 to this Annex, paragraph 2, for target road load, F_{tj}, at each reference speed, v_j.

$$\varepsilon_j = \frac{F_{sj} - F_{tj}}{F_{tj}} \times 100 \quad (58)$$

$\frac{C_{jm}}{r'}$ obtained in paragraph 2.1. of Appendix 1 to this 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

The chassis dynamometer setting load shall be adjusted according to the procedure specified in paragraph 2. of Appendix 2 to Annex 4. 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 4.3.1.1.3. The coastdown times shall be recorded.

Annex 4 – Appendix 1

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 Annex, calculation of the simulated road load, F_{sj}, for each reference speed, v_j, shall be conducted as described in paragraphs 1.1. to 1.3. inclusive of this Appendix.

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 ;

Δt_j is the coastdown time corresponding to speed v_j, seconds (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}:

$$F_s = A_s + B_s v + C_s v^2 \quad (2)$$

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 Annex 4, calculation of the simulated road load, F_{sj}, for each reference speed v_j, shall be conducted as described in paragraphs 2.1. to 2.3. inclusive of this Appendix.

2.1. The mean speed v_{jm}, and the mean torque, C_{jm}, 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 i^{th} data set, km/h;

k is the number of data sets;

C_{ji} is the torque of the i^{th} 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 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;

α_j is the mean acceleration, m/s^2, which shall be calculated using the following 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 i^{th} data set was sampled, seconds (s);

r'_j is the dynamic radius of the tyre, metres, for the j^{th} 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:

$$F_{sj} = \frac{f_{sj}}{r'} = \frac{a_s + b_s v_j + c_s v_j^2}{r'} \quad (10)$$

Annex 4–- Appendix 2

1. Chassis dynamometer load setting Adjustment of chassis dynamometer load setting using the coastdown method

The chassis dynamometer load setting shall be adjusted using the following equations:

$$F_{dj}^{*} = F_{dj} - F_{j} = F_{dj} - F_{sj} + F_{tj} =$$

$$= \left(A_d + B_d v_j + C_d v_j^2\right) - \left(A_s + B_s v_j + C_s v_j^2\right) + \left(A_t + B_t v_j + C_t v_j^2\right) =$$

$$= (A_d + A_t - A_s) + (B_d + B_t - B_s) v_j + (C_d + C_t - C_s) v_j^2 \quad (1)$$

Therefore:

$$A_d^{*} = A_d + A_t - A_s \quad (2)$$

$$B_d^{*} = B_d + B_t - B_s \quad (3)$$

$$C_d^{*} = C_d + C_t - C_s \quad (4)$$

The parameters used in these equations are the following:

F_{dj} 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 $\left(F_{sj} - F_{tj}\right)$, 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.

2. Adjustment of chassis dynamometer load setting using the torque meter method

The chassis dynamometer load setting shall be adjusted using the following equation:

$$F_{dj}^{*} = F_{dj} - \frac{F_{ej}}{r'} = F_{dj} - \frac{F_{sj}}{r'} + \frac{F_{tj}}{r'} =$$

$$= \left(A_d + B_d v_j + C_d v_j^2\right) - \frac{\left(a_s + b_s v_j + c_s v_j^2\right)}{r'} + \frac{\left(a_t + b_t v_j + c_t v_j^2\right)}{r'} =$$

$$= \left\{A_d + \frac{(a_t - a_s)}{r'}\right\} + \left\{B_d + \frac{(b_t - b_t)}{r'}\right\} v_j + \left\{C_d + \frac{(c_t - c_s)}{r'}\right\} v_j^2 \quad (5)$$

Therefore:

$$A_d^{*} = A_d + \frac{a_t - a_s}{r'} \quad (6)$$

$$B_d^{*} = B_d + \frac{b_t - b_s}{r'} \quad (7)$$

$$C_d^{*} = C_d + \frac{c_t - c_s}{r'} \quad (8)$$

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_i' values calculated in Appendix 1 to Annex 4, paragraph 2.1.

Annex 5

Test equipment and calibrations

1. Test bench specifications and settings

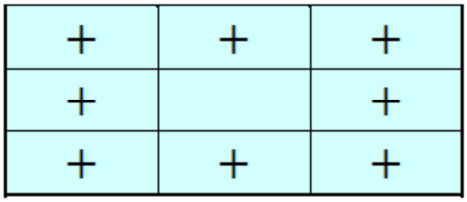
1.1. Cooling fan specifications

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:

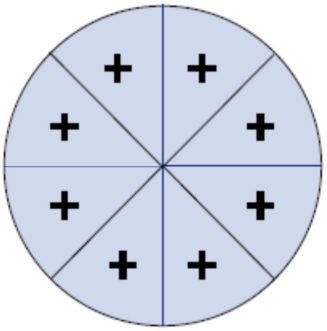
(a) For fans with rectangular outlets, are located at the centre of each rectangle dividing the whole of the fan outlet into 9 areas (dividing both horizontal and vertical sides of the fan outlet into 3 equal parts). The centre area shall not be measured (as shown in Figure A5/1);

Figure A5/1
Fan with Rectangular Outlet



(b) For circular fan outlets, the outlet shall be divided into 8 equal sectors by vertical, horizontal and 45° lines. The measurement points lie on the radial centre line of each sector (22.5°) at two–-thirds of the outlet radius (as shown in Figure A5/2).

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.

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 metre.

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 responsible authority.

1.1.6. In the cases described above, the cooling fan position (height and distance) shall be recorded and shall be used for any subsequent testing.

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-roller 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 roller 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 shall 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. Upon initial installation and after major maintenance, the requirements of paragraph 2.3.1.2.1. and either paragraph 2.3.1.2.2 or 2.3.1.2.3 shall be satisfied. The speed difference between the front and rear rollers is assessed by applying a 1 second moving average filter to roller speed data acquired at a minimum frequency of 20 Hz. er

2.3.1.2.1. The difference in distance covered by the front and rear rollers shall be less than 0.2 per cent of the distance driven over the WLTC. The absolute number shall be integrated for the calculation of the total difference in distance over the WLTC. erer

2.3.1.2.2. The difference in distance covered by the front and rear rollers shall be less than 0.1 m in any 200 ms time period.

2.3.1.2.3. The speed difference of all roller speeds shall be within +/- 0.16 km/h.

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 reference speed point.

3. Exhaust gas dilution system

3.1. System specification

3.1.1. Overview

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.

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 Annex.

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.

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 concentration of any compound 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 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 metres long, or less than 6.1 metres 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 673 K (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 343 K (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 responsible 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 pass 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 PM and PN levels, which can then be subtracted from the values measured in the diluted exhaust. See paragraph 1.2.1.3. of Annex 6.

3.3.3. Dilution tunnel

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.

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 (± 6 °C) of the specified operating temperature for a PDP CVS, ± 11 K (± 11 °C) for a CFV CVS, ± 6 K (± 6 °C) for a USM CVS, and ± 11 K (± 11 °C) 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 (± 1 °C) and a response time of 0.1 seconds 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. See Table A5/5.

3.3.6. Recommended system description

Figure A5/3 is a schematic drawing of exhaust dilution systems which meet the requirements of this 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 be 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;

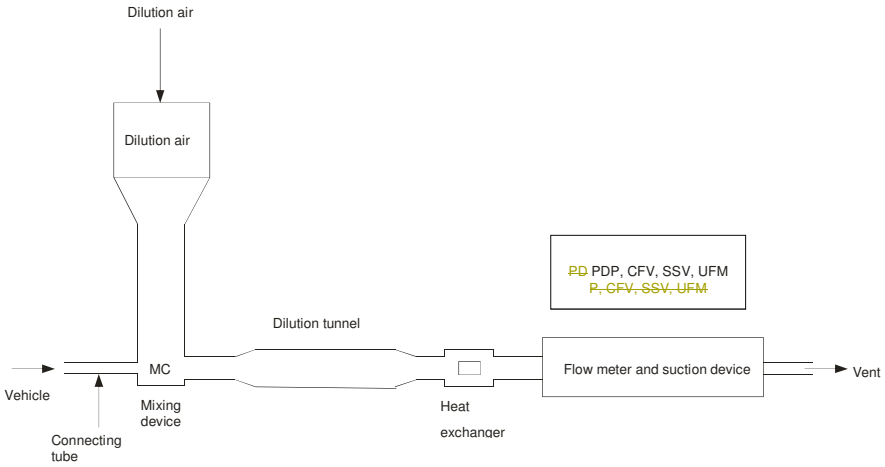
(e) A dilution tunnel from which particulates and particles are sampled;

(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.

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 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 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 Annex are met.

3.3.6.2.3. A measuring CFV tube shall measure the flow volume of the diluted exhaust gas.

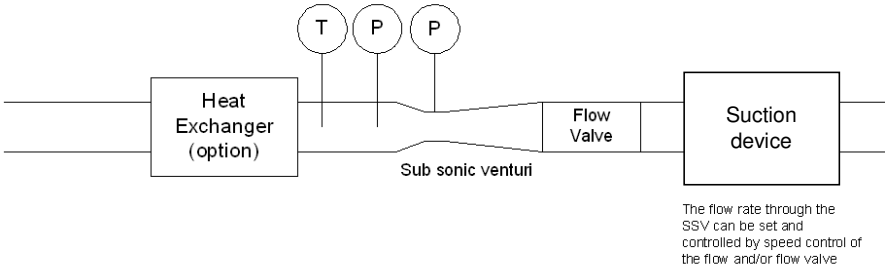
3.3.6.3. Subsonic flow venturi (SSV)

3.3.6.3.1. The use of an SSV (Figure A5/4) for a full flow exhaust dilution system is based on the principles of flow mechanics. The variable 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 Venturi 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:

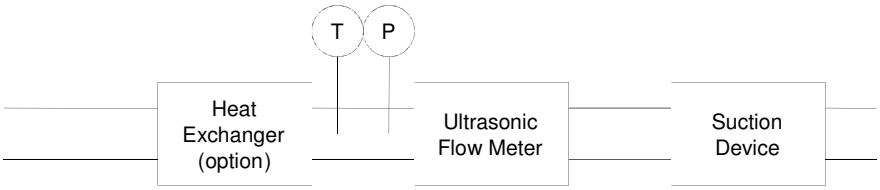
(a) A suction device fitted with speed control, flow valve or other method for setting the CVS flow rate and also for maintaining constant volumetric flow at standard conditions;

(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 shall 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 (± 6 °C) 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 (± 1 °C) 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.

Comment [SMD67]: OPEN POINT: 01.02.2015. Is "accuracy less than" meant or "an accuracy of at least"?

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

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 (± 1 °C) in temperature are acceptable as long as they occur over a period of several minutes.

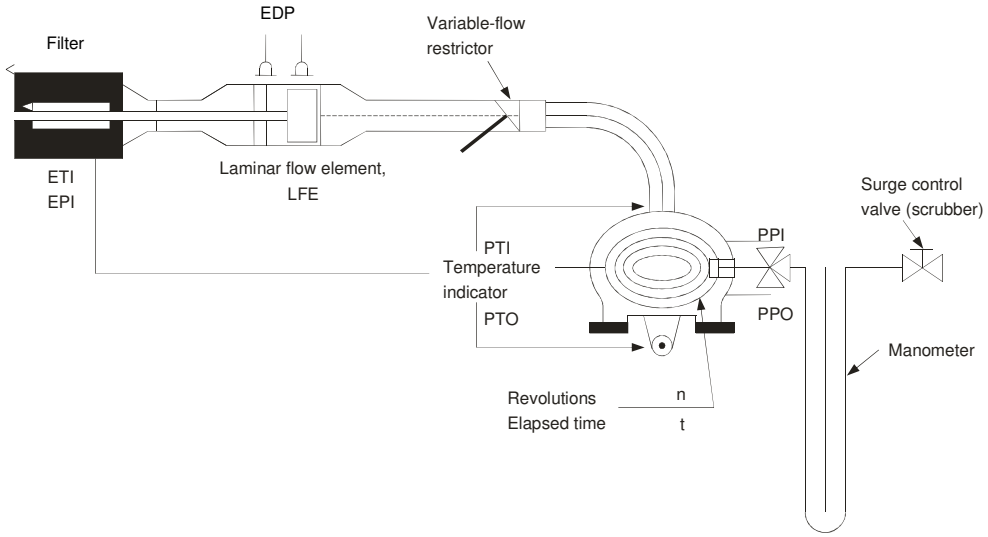
3.4.2.2.3. All connections between the flow meter and the CVS pump shall be free of leakage.

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 Annex shows an example of a calibration set-up. Variations are permissible, provided that the responsible 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

Figure A5/6
PDP Calibration Configuration



3.4.2.5. After the system has been connected as shown in Figure A5/6 of this Annex, the variable restrictor shall be set in the wide-open position and the CVS pump shall run for 20 minutes before starting the calibration.

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.

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.

$$V_0 = \frac{Q_s}{n} \times \frac{T_p}{273.15\ K} \times \frac{101.325\ kPa}{P_p} \quad (1)$$

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 (0 °C), 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:

$$x_0 = \frac{1}{n}\sqrt{\frac{\Delta P_p}{P_e}} \quad (2)$$

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 squares fit is performed to generate the calibration equations having the following form:

$$V_0 = D_0 - M \times x_0 \quad (3)$$

$$n = A - B \times \Delta P_p \quad (4)$$

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.

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:

$$Q_s = \frac{K_v P}{\sqrt{T}} \quad (5)$$

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.

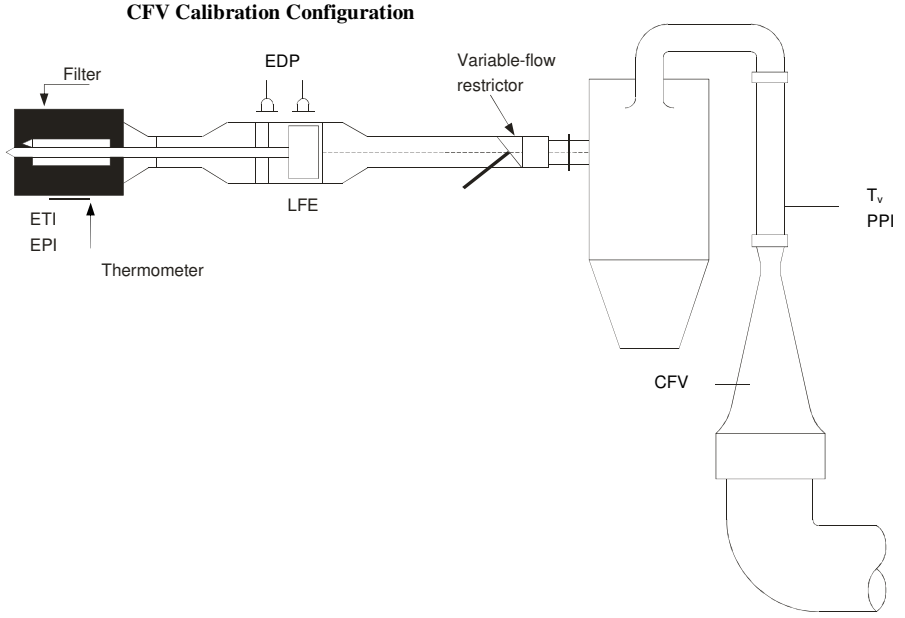
3.4.3.2. Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given:

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.

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 (0 °C) 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.

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 shall 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:

$$C_d = \frac{Q_{SSV}}{d_V^2 \times p_p \times \sqrt{\left\{\frac{1}{T} \times (r_p^{1.426} - r_p^{1.713}) \times \left(\frac{1}{1 - r_D^4 \times r_p^{1.426}}\right)\right\}}} \quad (7)$$

where:

Q_{SSV} is the airflow rate at standard conditions (101.325 kPa, 273.15 K (0 °C)), 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 Reynolds number, Re, at the SSV throat. The Reynolds number at the SSV throat shall be calculated using the following equation:

$$Re = A_1 \times \frac{Q_{SSV}}{d_V \times \mu} \quad (8)$$

where:

$$\mu = \frac{b \times T^{1.5}}{S + T} \quad (9)$$

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 (0 °C)), m^3/s;

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 shall 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 shall be within ± 0.5 per cent of the measured C_d for each calibration point.

3.4.5. Calibration of an ultrasonic flow meter (UFM)

3.4.5.1. The UFM shall be calibrated against a suitable reference flow meter.

3.4.5.2. The UFM shall 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.

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 (temperature and pressure sensors) of the UFM.

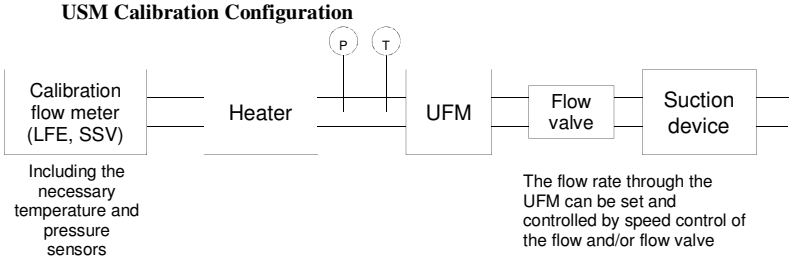
3.4.5.6. Measurements for flow calibration of the ultrasonic flow meter are required and the following data (in the case of the use of a laminar flow element) shall be found within the limits of precision given:

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. Its speed and/or the position of the flow valve shall 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 will 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.

$$K_v = \frac{Q_{reference}}{Q_s} \quad (10)$$

where:

Q_s is the air flow rate at standard conditions (101.325 kPa, 273.15 K (0 °C)), m^3/s;

$Q_{reference}$ is the air flow rate of the calibration flow meter at standard conditions (101.325 kPa, 273.15 K (0 °C)), 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 under normal test conditions and subsequently analysing and calculating the emission gas compounds according to the equations of Annex 7. The CFO (paragraph 3.5.1.1.1. of this Annex) and gravimetric methods (paragraph 3.5.1.1.2. of this 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 mass of pure carbon monoxide, carbon dioxide or propane gas 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). 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 sample bag is analysed by the usual equipment (paragraph 4.1. of this Annex) and the results compared to the concentration of the gas samples which was known beforehand. If deviations exceed 2 per cent, the cause of the malfunction shall be determined and corrected.

3.5.1.1.2. Gravimetric method

The gravimetric method weighs a 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 under normal exhaust emission test conditions 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 (paragraph 4.1. of this Annex). The results shall then be compared to the concentration figures computed previously. If deviations exceed 2 per cent, the cause of the malfunction shall be determined and corrected.

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. The mass of gaseous emissions shall be determined from the proportional sample concentrations and the total volume measured during the test. 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. (PM measurement equipment) and paragraph 4.3. (PN measurement equipment) of this Annex, the dilute exhaust gas sample may be taken downstream of the conditioning devices (if any).

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 sample bags, the connections sealing themselves automatically on the bag side. Other systems may be used for conveying the samples to the analyser (e.g. three-way stop valves).

4.1.2.10. Sample storage

4.1.2.10.1. The gas samples shall be collected in sample bags of sufficient capacity so as 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 and 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 ± 10 K (190 °C ± 10 °C) 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.

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.

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

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).

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 ± 10 K (190 °C ± 10 °C). It shall be calibrated with propane gas expressed equivalent to carbon atoms (C_1).

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) combined with a non-methane cutter (NMC-FID), 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.

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 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 shall 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 shall have combined interference that is within 0.0 ± 0.1 ppm.

4.1.4.11. Hydrogen (H_2) analysis (where applicable)

The analyser shall be of the sector field mass spectrometer type.

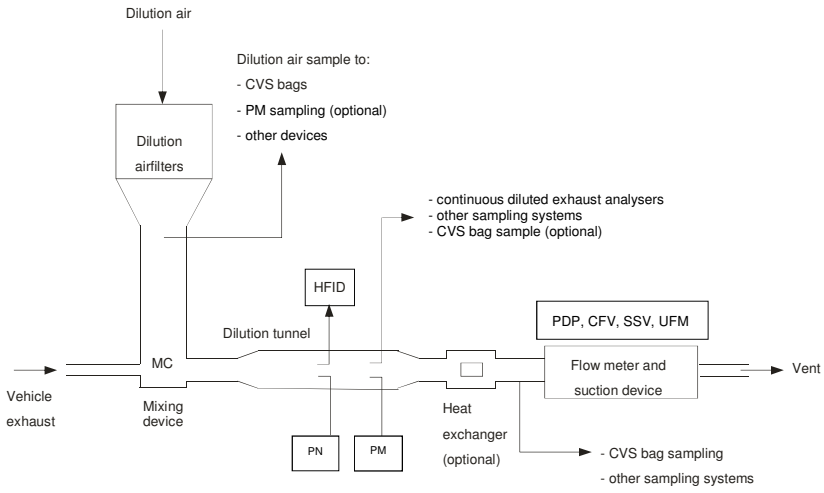
Comment [SMD68]: EXPERT PROPOSAL: April 2015 drafting meeting, Stockholm

4.1.5. Recommended system descriptions

4.1.5.1. Figure A5/9 is a schematic drawing of the gaseous emissions sampling system.

Figure A5/9
Full Flow Exhaust Dilution System Schematic

Comment [SMD69]: Completely new diagram. The previous diagram was mistakenly a double of diagram A5/3.



4.1.5.2. Examples of system components are as listed below.

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 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 sample bags or to the outside vent.

4.1.5.2.5. Gas-tight, quick-lock coupling elements between the quick-acting valves and the sample 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.

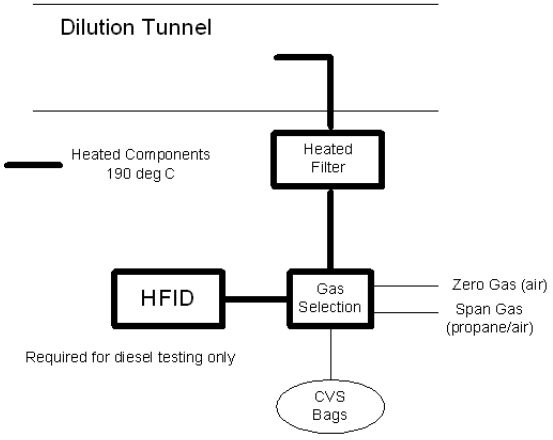
4.1.5.3.2. Heated filter located after the sampling point and before the HFID.

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. PM measurement equipment

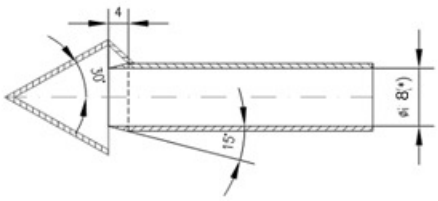
4.2.1. Specification

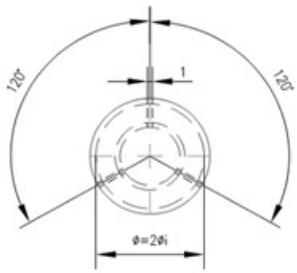
4.2.1.1. System overview

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 A5/12 and A5/13.

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.

Figure A5/11
Alternative Particulate Sampling Probe Configuration





(*) Minimum internal diameter
Wall thickness ~ 1 mm - Material: stainless steel

Comment [SMD70]: CONFIRMATION: This diagram moved to here at the March 2015 drafting meeting.

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 shall be made during the commissioning of the system and as required by the responsible 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 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 shall be increased or double dilution shall 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 measurement shall be measured with an accuracy of ± 1 K (± 1 °C) and a response time ($t_{10}-t_{90}$) of 15 seconds or less.

4.2.1.2.8. The 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 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 filter shall be of a higher accuracy.

4.2.1.2.9. All data channels required for the PM 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) sampling flow rate;

(c) secondary dilution air flow rate (if secondary dilution is used);

(d) 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}, defined in paragraph 3.2.2.of Annex 7, in the equation is not measured directly but determined by differential flow measurement

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 shall 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 A5/12
Particulate Sampling System

Comment [SMD71]: OPEN POINT: March 2015 drafting meeting: the quality of the diagram will be improved (see L. Hill mail).

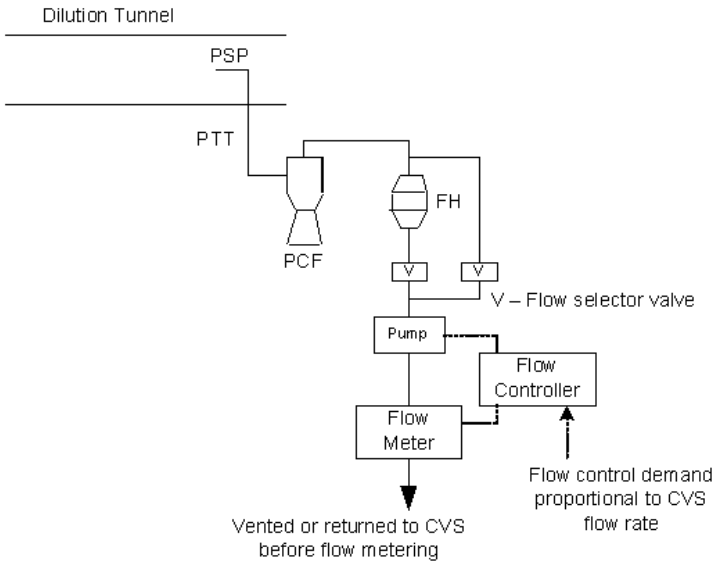
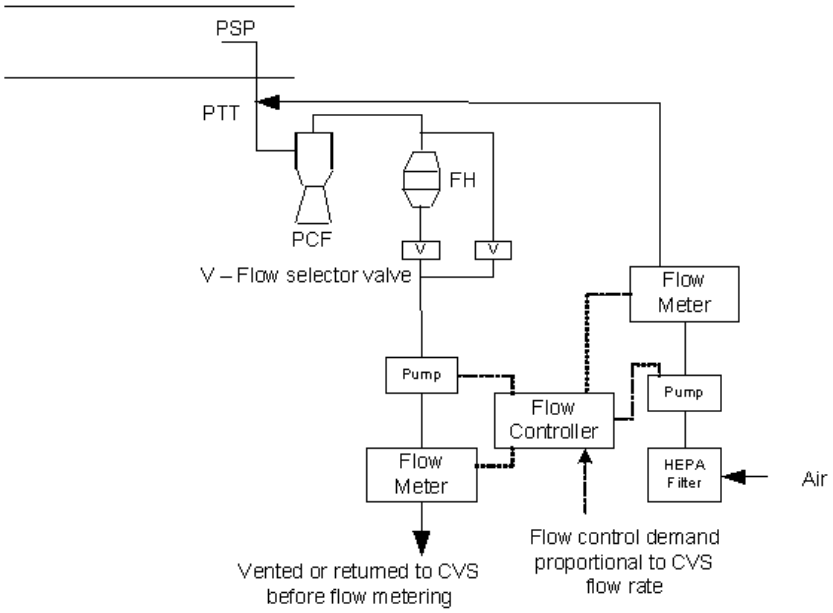


Figure A5/13
Double Dilution Particulate Sampling System



4.2.1.3. Specific requirements

4.2.1.3.1. Sample 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 sample probe, such as that indicated in Figure A5/11, may alternatively be used provided it achieves the pre-classification performance described in paragraph 4.2.1.3.1.4. below.

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 PM. 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 PM. However, a sampling probe, acting as an appropriate size-classification device, such as that shown in Figure A5/11, is acceptable as an alternative to a separate pre-classifier as long as it fulfils the previously mentioned requirements.

Comment [SMD72]: OPEN POINT: April 2015 drafting meeting, Stockholm. What does "previously mentioned requirements" refer to?

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 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 be 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. If the double diluted 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 sampling flow meter has real time monitoring and flow control operating at a frequency of 1 Hz or faster;

(b) During regeneration tests on vehicles equipped with periodically regenerating after-treatment devices.

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 an initial value within the range 20 cm/s to 105 cm/s and shall 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

(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) Limited deviations from weighing room temperature and humidity specifications shall be allowed provided their total duration does not exceed 30 minutes in any one filter conditioning period.

(d) The levels of ambient contaminants in the chamber (or room) environment that would settle on the particulate filters during their stabilisation shall be minimised.

(e) During the weighing operation no deviations from the specified conditions are permitted.

4.2.2.2. Linear response of an analytical balance

The analytical balance used to determine the filter weight shall meet the linearity verification criteria of Table A5/1 below applying linear regression. This implies a precision (standard deviation) of at least 2 µg and a resolution of at least 1 µg (1 digit = 1 µg). At least 4 equally-spaced reference weights shall be tested. The zero value shall be within 1 µg.

Comment [SMD73]: EXPERT PROPOSAL: April 2015 drafting meeting, Stockholm.

Comment [SMD74]: EXPERT PROPOSAL: April 2015 drafting meeting, Stockholm.

Table A5/1
Analytical Balance Verification Criteria

Measurement system	Intercept a0	Slope a1	Standard error SEE	Coefficient of determination r^2
PM Balance	≤ 1 µg	0.99 – 1.01	≤ 1per cent max	≥ 0.998

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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 particulate matter itself.

If the density of the filter material is not known, the following densities shall be used:

(a) PTFE coated glass fiber 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 shall be known and be used. International Recommendation OIML R 111-1 Edition

2004(E) (or equivalent) from International Organization of Legal Metrology on calibration weights should be followed.

The following equation shall be used:

$$m_f = m_{uncorr} \times \left(\frac{1-\frac{\rho_a}{\rho_w}}{1-\frac{\rho_a}{\rho_f}} \right) \quad (11)$$

where:

m_f is the corrected particulate mass, mg;

m_{uncorr} is the uncorrected particulate 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 $\rho_a$shall be calculated as follows:

$$\rho_a = \frac{p_b \times M_{mix}}{R \times T_a} \quad (12)$$

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. 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. 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.

A sample probe acting as an appropriate size-classification device, such as that shown in Figure A5/11, is an acceptable alternative to the use of a particle size pre-classifier.

4.3.1.2. General requirements

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 shall 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 shall 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

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 308 K (35 °C) at the inlet to the PNC;

(b) Include an initial heated dilution stage which outputs a sample at a temperature of ≥ 423 K (150 °C) and ≤ 623 K ± 10 K (350 °C ± 10 °C), and dilutes by a factor of at least 10;

(c) Control heated stages to constant nominal operating temperatures, within the range ≥ 423 K (150 °C) and ≤ 673 K ± 10 K (400 °C ± 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:

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)} \quad (13)$$

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, $\overline{f_r}$, at a given dilution setting shall be calculated as follows:

$$\overline{f_r} = \frac{f_r(30\text{ nm}) + f_r(50\text{ nm}) + f_r(100\text{ nm})}{3} \quad (14)$$

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;

(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 per 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 per cm³ to the upper threshold of the single particle count mode of the PNC against a traceable standard. At concentrations below 100 per cm³ measurements averaged over extended sampling periods may be required to demonstrate the accuracy of the PNC with a high degree of statistical confidence;

(c) Have a resolution of at least 0.1 particles per cm³ at concentrations below 100 per cm³;

(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 a frequency of 0.5Hz;

(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 Annex but shall not make use of any other algorithm to correct for or define the counting efficiency;

(h) Have counting efficiencies at the different particle sizes as specified in Table A5/2.

Table A5/2
PCN Counting Efficiency

Particle size electrical mobility diameter (nm)	PCN 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.

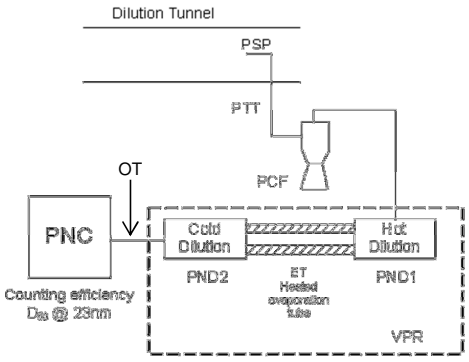
4.3.1.3.6. Where they are not held at a known constant level at the point at which PNC flow rate is controlled, the pressure and/or temperature at PNC inlet shall be measured and recorded for the purposes of correcting particle concentration measurements to standard conditions.

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.

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 Annex are acceptable.

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.

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.

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

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) Analyser and gas component;

(b) Range;

(c) Date of linearisation.

5.2.2.6. If it can be shown to the satisfaction of the responsible 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 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 Annex 6.

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 shall 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 Annex shall be established.

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).

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 an 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.

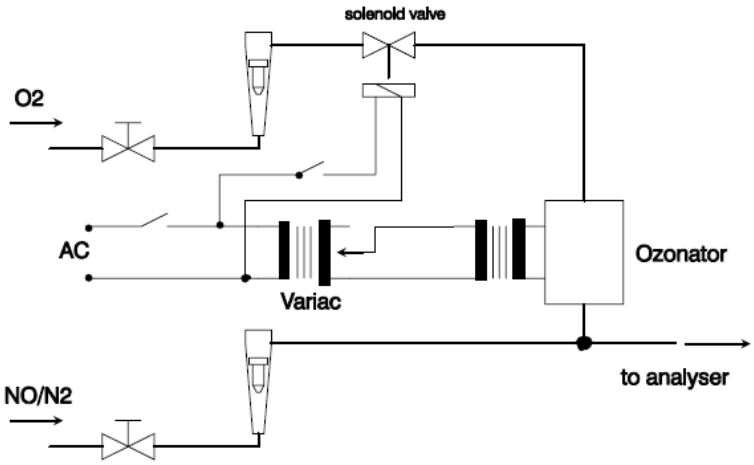
5.5.1.2. Via a T-fitting, oxygen or synthetic air shall be added continuously to the calibration gas flow until the concentration indicated is approximately 10 per cent less than the indicated calibration concentration given in paragraph 5.5.1.1. above. The indicated concentration (c) shall be recorded. 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.

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.

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. inclusive above as follows:

$$\text{Efficiency} = \left(1 + \frac{a-b}{c-d}\right) \times 100 \qquad (15)$$

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 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.

5.7. Calibration and validation of the particle sampling system

Examples of calibration/validation methods are available at: http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/pmpFCP.html.

5.7.1. Calibration of the particle number counter

5.7.1.1. The responsible 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 shall be monitored for deterioration or the PNC wick shall 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 PC.

Figure A5/16
Nominal PNC Annual Sequence

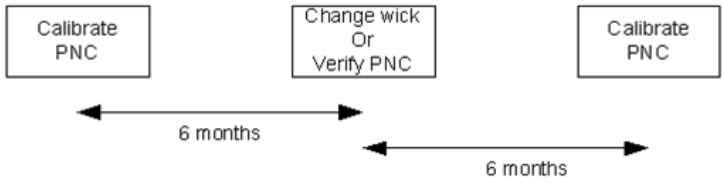
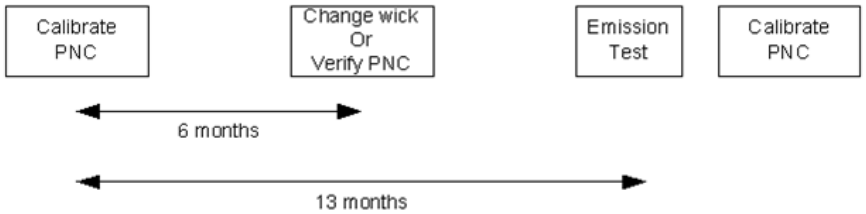


Figure A5/17
Extended PNC Annual Sequence (in the case where full PNC calibration is delayed)



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 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.

5.7.1.3.2. In 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 per cm³, the remaining

concentrations shall be linearly spaced between 1,000 per cm³ and the maximum of the PNC's range in single particle count mode.

5.7.1.3.3. In 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) 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 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 responsible 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, 50 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, $\overline{f_r}$, 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 per cm³ at the VPR inlet. As an option, a polydisperse aerosol 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.

The particle concentration reduction factor for each monodisperse particle size, $f_r(d_i)$, shall be calculated as follows:

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)} \quad (16)$$

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, $\overline{f_r}$, at a given dilution setting shall be calculated as follows:

$$\overline{f_r} = \frac{f_r(30nm) + f_r(50nm) + f_r(100nm)}{3} \quad (17)$$

Where a polydisperse 50 nm aerosol is used for validation, the mean particle concentration reduction factor, $\overline{f_v}$, at the dilution setting used for validation shall be calculated as follows:

$$\overline{f_v} = \frac{N_{in}}{N_{out}} \quad (18)$$

where:

N_{in} is the upstream particle number concentration;

N_{out} is the downstream particle number concentration.

5.7.2.3. 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 per cm³ when operated at its minimum dilution setting and manufacturers recommended operating temperature.

5.7.3. Particle number system check procedures

5.7.3.1. On a monthly basis, the flow into the particle counter shall have 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 shall 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 C1, ≤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 C1, ≤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 C1, ≤ 400 ppm CO2; hydrogen content between 39 and 41 per cent volume;

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 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 for NH_3 analysis

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 (intensity/wavelength) is calculated from the measured interferogram (intensity/time) by means of the Fourier transform method. ~~An FTIR employs~~

Comment [SMD75]: EXPERT PROPOSAL: 28.11.2014: from AP (Cova) during WLTP IWG #8 Pune

~~the broad waveband infrared spectroscopy principle. It allows simultaneous measurement of exhaust components whose standardized spectra are available in the instrument. The absorption spectrum (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.

7.1.1.3. Extractive sampling

The sample path upstream of the analyser (sampling line, prefilter(s), pumps and valves) shall be made of stainless steel or PTFE, and shall be heated to set points between 383 K (110 °C) and 463 K (190 °C) in order to minimise NH_3 losses and sampling artefacts. In addition, the sampling line shall be as short as possible. At the manufacturer's request, temperatures between 383 K (110 °C) and 406 K (133 °C) may be chosen.~~.~~

7.1.1.~~3~~4. Measurement cross interference

7.1.1.~~3~~4.1. The spectral resolution of the target wavelength shall be within 0.5 per cm in order to minimize cross interference from other gases present in the exhaust gas.

7.1.1.4.2. Analyser response shall not exceed ± 2 ppm at the maximum CO_2 and H_2O concentration expected during the vehicle test.

7.1.1.4. In order not to influence the results of downstream measurement, the amount of sample lost shall be limited by in-situ measurement, low flow analysers or return of by-pass flow. The maximum volume of by-pass flow shall be calculated as follows:

$$Flow_lost_max = \frac{0.005 \times V_{mix}}{DF} \quad (19)$$

where:

$Flow_lost_max$ is the maximum return by-pass flow, volume/sec;

V_{mix} is the volume of diluted exhaust per phase;

DF is the dilution factor.

7.2. Sampling and analysis methods for N_2O

7.2.1. Gas chromatographic method

7.2.1.1. General description

Followed by 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~~ During each phase of the test, a gas sample shall be taken from the corresponding diluted exhaust bag and dilution air bag for analysis. Alternatively, a~~A~~ single composite dilution background sample can be analysed ~~instead~~ (not possible for phase weighing).

7.2.1.2.1. Sample transfer

Comment [SMD76]: EXPERT PROPOSAL: 28.11.2014: from AP (Cova) during WLTP IWG #8 Pune

Comment [SMD77]: CONFIRMATION: March 2015 drafting meeting.
Cova to get back to DC regarding the text in brackets.

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.

7.2.1.2.2. Sample storage

Secondary sample storage bags shall be analysed within 24 hours and shall be stored at room temperature.

7.2.1.3. Instrumentation and apparatus

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 shall 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 shall be taken into consideration when setting up the method to achieve adequate N_2O peak resolution. Whenever possible, the operator shall 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

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 responsible authority.

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 performing 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 shall 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 shall 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.

7.2.1.7.2. A quality control standard shall be analysed within 24 hours before the analysis of the sample.

~~7.2.1.8. Calculations~~

$$\text{Conc.}\,N_2O = \text{PeakArea}_{\text{sample}} \times \text{ResponseFactor}_{\text{sample}}$$

$$\text{ResponseFactor}_{\text{sample}} = \frac{\text{Concentration}_{\text{standard (ppb)}}}{\text{PeakArea}_{\text{standard}}}$$

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):

Limit of Detection: $\text{LoD} = \text{avg.}(\text{noise}) + 3 \times \text{std.dev.}$ (20)

where std. dev. is considered to be equal to noise.

Limit of Quantification: $\text{LoQ} = 3 \times \text{LoD}$ (21)

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.

[RESERVED: 7.3. Sampling and analysis methods for ethanol (EtOH….]

[RESERVED 7.4. Sampling and analysis methods for formaldehyde and acetaldehyde]

Comment [SMD78]: CONFIRMATION: March 2015 drafting meeting.
DC: check equation numbers.

Comment [SMD79]: 15.04.2015: to be moved to N2O in Annex 7

Comment [SMD80]: EXPERT PROPOSAL: April 2015 drafting meeting, Stockholm. T. Adam that 7.2.1.8. to remain here.
DC: Annex 7 still in progress.

Annex 6

Type 1 test procedures and test conditions

1. Test procedures and test conditions

1.1 Description of tests

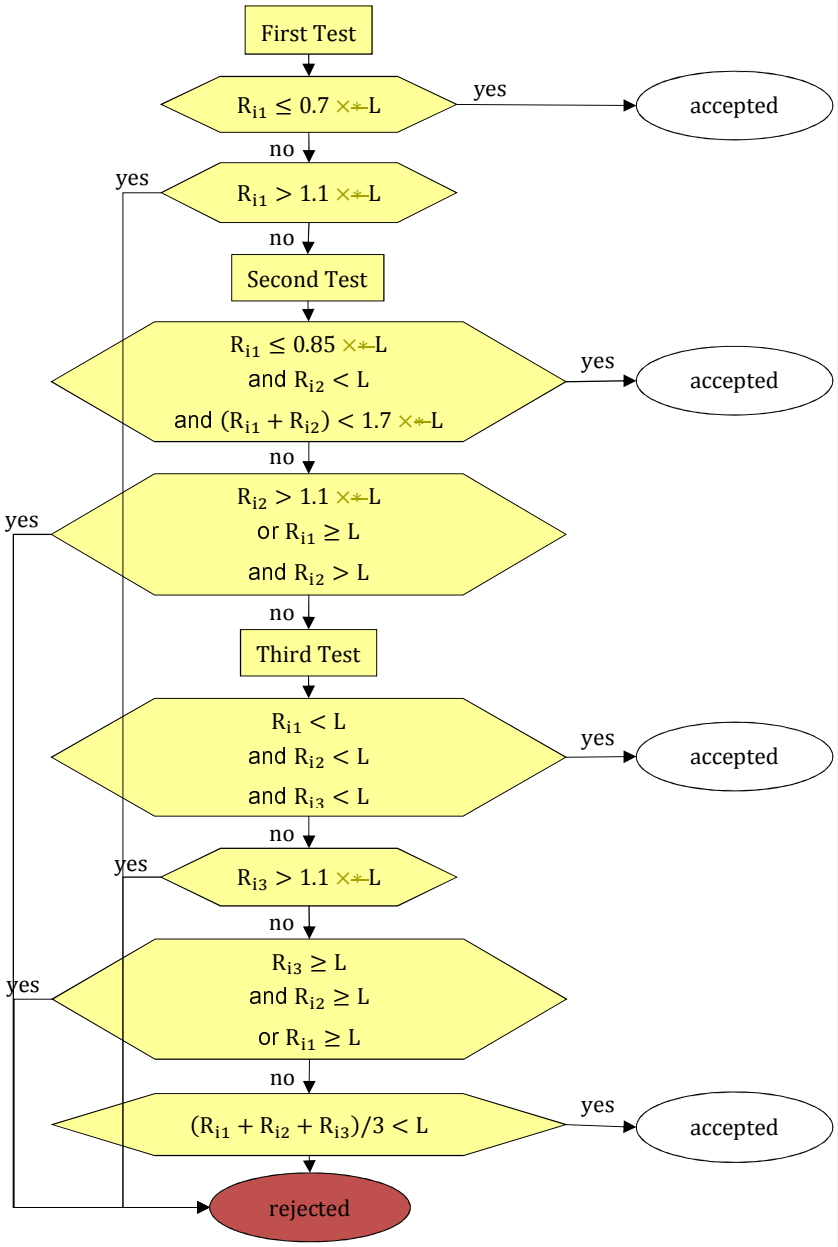
1.1.1. The tests verify the emissions of gaseous compounds, particulate matter, particle number, CO_2 emissions, and fuel consumption, in a characteristic driving cycle.

1.1.1.1. The tests shall be carried out by the method described in paragraph 1.2. of this 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 by the Contracting Parties. If a vehicle configuration must be driven more than once to show compliance with regional limits (as defined in FigureA6/1), the average CO_2 value shall be calculated.

Figure A6/1
Flowchart for the Number of Type 1 Tests

Comment [SMD81]: OPEN POINT: 02.04.2015.



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 interpolation 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 PM measurement

1.2.1.3.1.1. Where the manufacturer requests and the Contracting Party permits 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. inclusive.

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, it 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 $\mu g/m^3$ 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 Contracting Party permits subtraction of either dilution air or dilution tunnel particle number background from emissions measurements or a 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 per cm^3) 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 Contracting Party or the manufacturer can request that actual background measurements are used instead of calculated ones.

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 particles per 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 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 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 (± 1.5 °C):

(a) Test cell ambient air

(b) Dilution and sampling system temperatures as required for emissions measurement systems defined in 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 (23 °C). The tolerance of the actual value shall be within ± 5 K (± 5 °C). The air temperature and humidity shall be measured at the vehicle cooling fan outlet at a minimum frequency of 1 Hz. For the temperature at the start of the test, see paragraph 1.2.8.1. in Annex 6.

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:

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

1.2.2.2.1.3. Humidity shall be measured continuously at a minimum frequency of 1 Hz.

1.2.2.2.2. Soak area

The soak area shall have a temperature set point of 296 K (23 °C) and the tolerance of the actual value shall be within ± 3 K (± 3 °C) 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 frequency 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 recorded. In selecting the test vehicle, the manufacturer and responsible authority shall agree which vehicle model is representative for the CO_2 interpolatione 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 Annex 7), an additional measurement of emissions shall be performed with the road load as determined with test vehicle L. Tests on vehicles H and L should be performed with the same test vehicle and shall be tested with the shortest final transmission ratio within the interpolation family.

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 responsible authority, the CO_2 interpolation line may be extrapolated to a maximum of 3 g/km above the CO_2 emission of vehicle H and/or below the CO_2 emission of vehicle L. This extension is valid only within the absolute boundaries of the interpolation range specified above.

1.2.3.3. Run-in

The vehicle shall be presented in good technical condition. It shall 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 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 responsible 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 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 recorded.

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 powertrain and vehicle controls shall be those prescribed by the manufacturer for series production.

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 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 recorded.

1.2.4.6. Reference fuel

1.2.4.6.1. The appropriate reference fuel as defined in 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.

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

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 subparagraphs 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 Annex 4.

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 Annex).

1.2.6.3.4. The drive-wheel tyre pressure shall be set in accordance with paragraph 1.2.4.5. of this Annex.

1.2.6.3.5. Between the tests on the first gaseous reference fuel and the second gaseous reference fuel, for vehicles with positive ignition engines 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 Annex.

The dynamometer shall be set according to Annex 4.

1.2.6.3.7. At the request of the manufacturer or responsible 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 recorded by the responsible authority.

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, 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 shall be repeated and a new test shall 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 frequency of not less than 1 Hz so that the actual driven speed can be assessed.

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 Annex 2 shall be followed. Vehicles tested according to Annex 8 shall be driven according to paragraph 1.6. of that 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 recorded.

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 shall be started and completed within ± 1.0 second of the prescribed gear shift point.

1.2.6.5.1.3. The clutch shall 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 fulfill the limits of criteria emissions in all automatic shift modes used for forward driving. The manufacturer shall give appropriate evidence to the responsible authority. Provided the manufacturer can give technical evidence with the agreement of the responsible 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 responsible authority of the existence of a mode that fulfils the requirements of paragraph 3.5.10. in section B of this gtr. With the agreement of the responsible 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.

1.2.6.5.2.4. If the vehicle has no predominant mode or the requested predominant mode is not agreed by the responsible 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 evidence provided 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 recorded. 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.

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 the first acceleration.

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 Annex.

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;

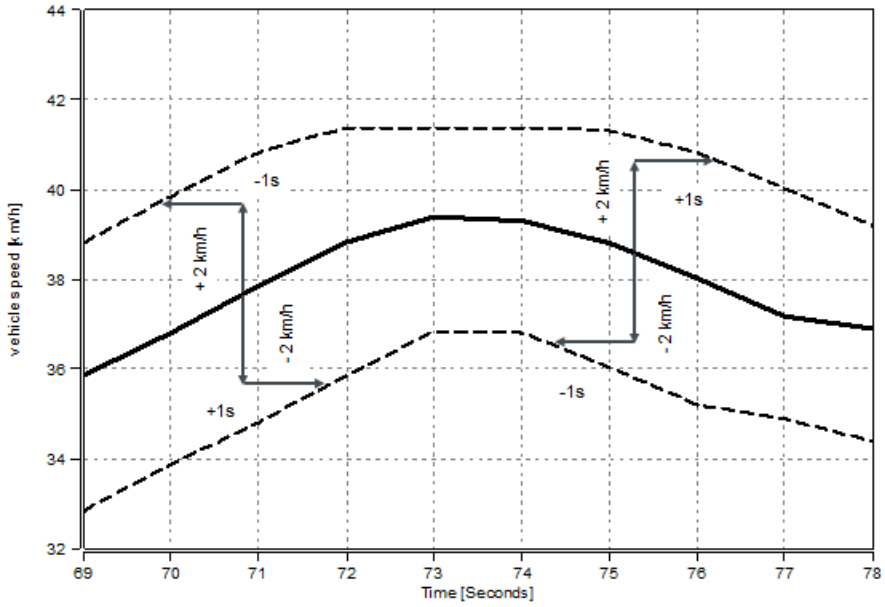
(b) The lower limit is 2.0 km/h lower than the lowest point of the trace within ± 1.0 second of the given time.

See Figure A6/2.

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.

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 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.

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.

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. If not excluded by specific provisions for a particular vehicle, cooling may be accomplished by forced cooling down to 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 (23 °C ± 3 °C) measured at minimum frequency of 1 Hz. The engine oil temperature and coolant temperature, if any, shall be within ± 2 K (± 2 °C) of the set point of 296 K (23 °C).

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. inclusive of this Annex over the applicable WLTC, as described in Annex 1.

1.2.8.6. RCB data shall be recorded for each phase of the WLTC as defined in Appendix 2 to this 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.

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 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 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 Annex 5.

1.2.10. Sampling for PM determination

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

1.2.10.1.2.1. 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.

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. inclusive.

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 per 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 per cm^3. Upon removal of the filter, the particle counter shall show an increase in measured concentration to at least 100 particles per cm^3 when sampling ambient air and a return to ≤ 0.2 particles per 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 PM and PN 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. The requirements of paragraph 1.2.10.1.1.1. shall apply.

1.2.12.6. Dynamometer distance shall be recorded for each phase.

1.2.13. Ending the test

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.Exhaust gases shall, in any event, be analysed 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 Annex 7.

1.2.14.2.9. It is not mandatory to perform calibration and check before and after each phase bag pair but can be done before and after the whole test. In that case, calibration and checks have to be done for all analyser ranges used for the text.

Comment [SMD82]: EXPERT PROPOSAL: 03.05.2015. From Kurt Engeljehringer.

1.2.14.2.9. Calibrations and checks may be performed for each bag pair:

Comment [SMD83]: EXPERT PROPOSAL: 03.05.2015. Modified by DC.

(a) before and after each test phase, or

(b) before and after the complete test.

In the case of (b), calibrations and checks shall be performed on all analysers for all ranges used during the test.

In both cases, (a) and (b), the same analyser range shall be used for corresponding ambient air and exhaust bags.

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.

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 shall 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 shall be discarded and replaced within 48 hours. In all other cases, reference filters shall 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 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.

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 Part II of this gtr.

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~~ shall 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. The provisions of this Appendix shall apply for the purposes of particulate mass measurements only and not particle number measurements.

1.4. At the request of the manufacturer, and subject to the agreement of the responsible 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 by the Contracting Party for the relevant vehicle category.

1.5. At the option of the Contracting Party, the Extra High$_2$ phase may be excluded for determining the regenerative factor, K_i, for Class 2 vehicles.

1.6. At the option of the Contracting Party, the Extra High$_3$ phase may 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 two) 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 measurements for at least two Type 1 cycles shall be completed: one immediately after regeneration (before new loading) and one as close as possible prior to a regeneration phase. All emissions

Comment [SMD84]: OPEN POINT: 02.04.2015. From Pune: Upon request of the manufacturer and with approval of the responsible authority, a manufacturer may develop an alternative procedure to demonstrate its equivalency, including filter temperature, loading quantity and distance. It can be done on an engine bench or on a chassis dynamometer.

Comment [SMD85]: OPEN POINT: 02.04.2015. Instead of carrying out the test procedures defined in this Appendix, a fixed Ki value of 1.05 may be used for CO2 and fuel consumption.

Comment [SMD86]: EXPERT PROPOSAL: 29.08.2014: This is from C. Hosier from October, 2013: Technical Secretary proposes also to include the provision that 'and CO2/fuel consumption are identical' – however if accepted, this needs a tolerance since the compared result is only a measured one not a limit. Propose postpone until phase 1B

Comment [SMD87]: 12.09.2014: Deadline for expert comments: 31.10.2014.

Comment [SMD88]: 19.11.2014: see wltp-08-33 for proposed text. Proposal:

At the request of the manufacturer and with approval of the authority an "engineering control unit" which has no effect on original engine calibrations can be used during ki determinati ... [8]

measurements shall be carried out according to this Annex and all calculations shall be carried out according to paragraph 3. of this Appendix.

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 recorded.

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 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 gtr 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 responsible 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 WLTC 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 shall be as short as possible. The engine shall not be switched off during this period.

Comment [SMD89]: EXPERT PROPOSAL: 14.09.2014: Type 1 cycle replaced by WLTC cycle. 12.09.2014: Deadline for expert comments: 31.10.2014.

Comment [SMD90]: CONFIRMATION: 02.12.2014: approved at WLTP IWG #8 in Pune. Nevertheless, mail sent to Ichikawa-san.

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 recorded.

3. Calculations

3.1. Calculation of the exhaust and CO_2 emissions, and fuel consumption of a single regenerative system

$$M_{si} = \frac{\sum_{j=1}^{n} M'_{sij}}{n} \text{ for } n \geq 1 \quad (1)$$

$$M_{ri} = \frac{\sum_{j=1}^{d} M'_{rij}}{d} \text{ for } d \geq 1 \quad (2)$$

$$M_{pi} = \frac{M_{si} \times D + M_{ri} \times d}{D+d} \quad (3)$$

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;

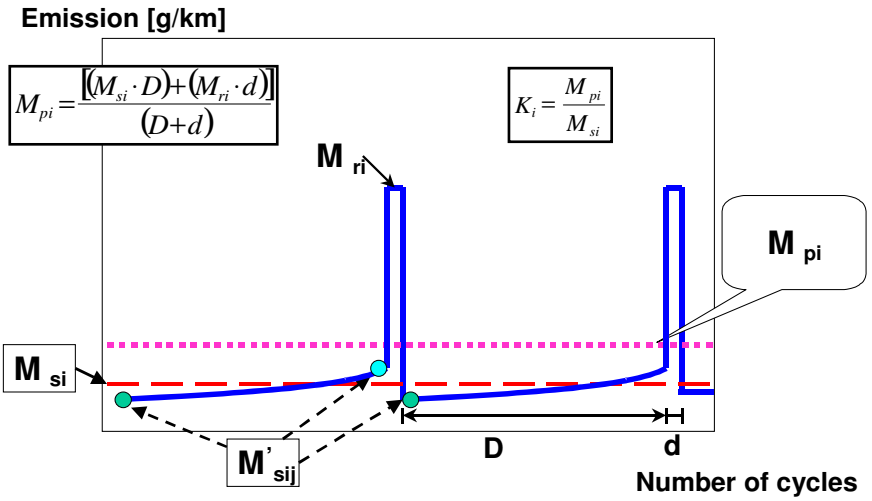
d is the number of complete operating cycles required for regeneration;

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.

Comment [SMD91]: EXPERT PROPOSAL: March 2015 drafting meeting. This paragraph to be reviewed by Ichikawa-san.

K_i factor: $K_i = \frac{M_{pi}}{M_{si}}$ (4)

K_i offset: $K_i = M_{pi} - M_{si}$ (5)

M_{si}, M_{pi} and K_i results, and the manufacturer's choice of type of factor shall be recorded.

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;

$M'_{rik,j}$ 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 $1 \leq j \leq d_k$, g/km;

Comment [SMD92]: OPEN POINT: 11.05.2014: H. Schmidt states that the text should remain as is, i.e., Msi, Mpi and Ki must be recorded. Comments from any other experts are welcome.

Comment [SMD93]: EXPERT PROPOSAL: 31.08.2014: Expert S. Carli approves statement from H. Schmidt.

Comment [SMD94]: 12.09.2014: Deadline for expert comments: 31.10.2014.

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;

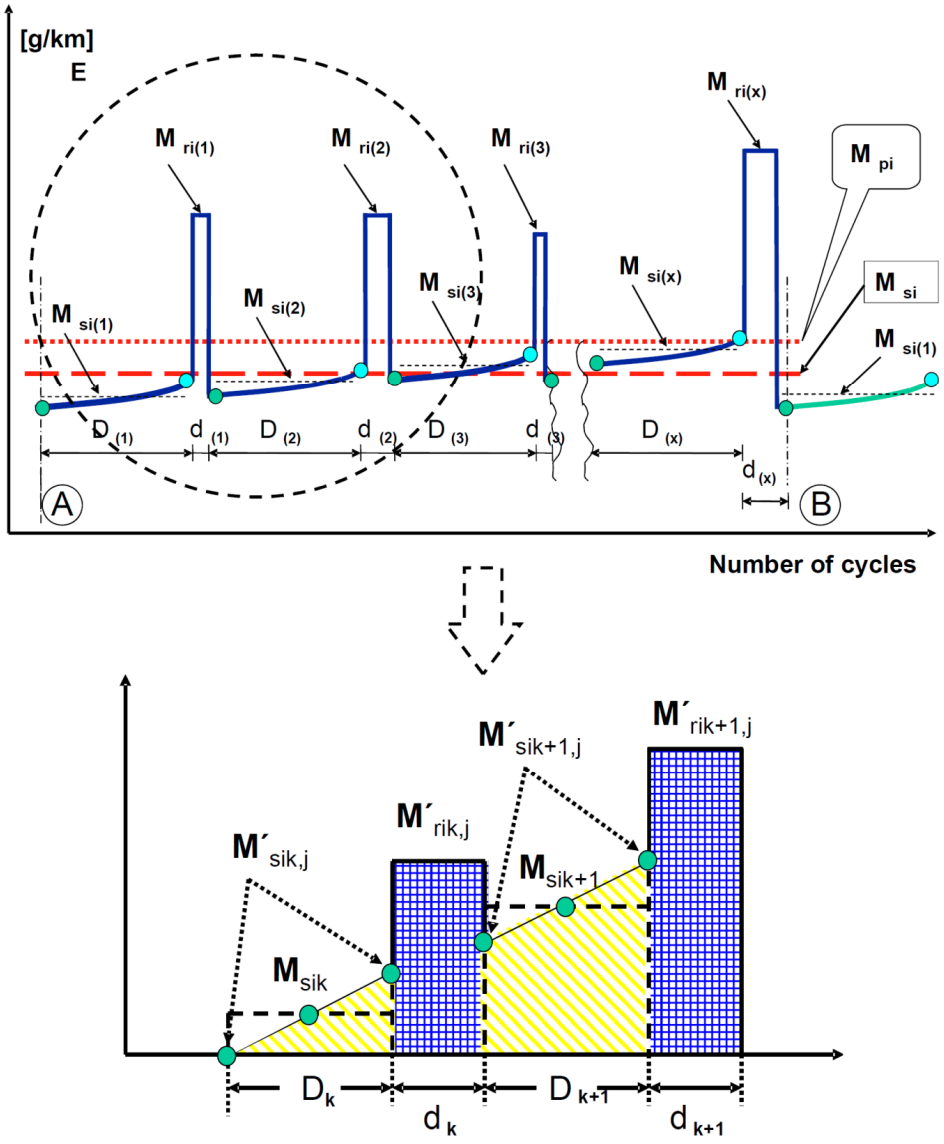
D_k is the number of complete operating cycles of event k between two cycles where regenerative phases occur;

x is the number of complete regeneration events.

The calculation of M_{pi} is shown graphically in Figure A6.App1/2.

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.

After performing the complete procedure (A to B, see Figure A6.App1/2), the original starting condition A should be reached again.

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 shall 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 responsible authority by providing the means to connect a current transducer to the battery cables in the above described manner.

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).

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 responsible authority.

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.

Comment [SMD95]: EXPERT PROPOSAL: 29.07.2014: From Dr. Ligterink (TNO): Dr. Norbert E. Ligterink relating to the work of his colleague, Gerrit Kadijk, highlights inconsistencies within the GTR concerning units used in Annex 6, Appendix 2 (Test procedure for electric power supply system monitoring). The problem is whether (a) kW.h, joules or megajoules should be used in equations, and, (b), whether kW.h, joules or megajoiules should be used in the Willans factors, and (c) whether the equations are all correct.This applies also to Annex 7 (Calculations) and to Annex 8 (Evs).

Comment [SMD96]: 12.09.2014: Deadline for expert comments: 31.10.2014.

The following family criteria shall be valid:

(a) Identical combustion processes (i.e. positive ignition, compression ignition, two-stroke, four-stroke);

(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. Measurement of the battery current shall start at the same time as the test starts and shall end immediately after the vehicle has driven the complete driving cycle.

3.2. 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 shall be determined for the total WLTC for the applicable vehicle class.

3.3. Separate values of Q_{phase} shall be logged over the cycle phases required to be driven for the applicable vehicle class.

3.4. $CO_{2,CS}$ and FC_{CS} test results shall be corrected as a function of the REESS energy balance, RCB.

3.5. 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 :

$$\Delta E_{REESS} \leq \text{RCB correction criterion} \quad (2)$$

Comment [SMD97]: March 2015 drafting meeting.
Net heating value is required to calculate Efuel. See under "Annex 6" in Fujiwara-san's table.

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 shall 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-specific 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:

$\Delta CO_{2,phase(i)}$ 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/MJ	0.0733	0.0778
		gCO_2/MJ	175	186
	Petrol (E5)	l/MJ	0.0744	0.0789
		gCO_2/MJ	174	185
	Petrol (E10)	l/MJ	0.0756	0.0803
		gCO_2/MJ	174	184
	CNG (G20)	m^3/MJ	0.0719	0.0764
		gCO_2/MJ	129	137
	LPG	l/MJ	0.0950	0.101
		gCO_2/MJ	155	164
	E85	l/MJ	0.102	0.108
		gCO_2/MJ	169	179
Compression ignition	Diesel (B0)	l/MJ	0.0611	0.0611
		gCO_2/MJ	161	161
	Diesel (B5)	l/MJ	0.0611	0.0611
		gCO_2/MJ	161	161
	Diesel (B7)	l/MJ	0.0611	0.0611
		gCO_2/MJ	161	161

Annex 7

Calculations

1. General requirements

1.1. Calculations related specifically to hybrid and pure electric vehicles are described in Annex 8.

1.2. The calculations described in this 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. Volume calculation for a variable dilution device capable of operating at a constant or variable flow rate

2.1.1. 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, litres per pump revolution;

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;

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's intake, combustion and exhaust processes 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 (0 °C) and 101.325 kPa:

Carbon monoxide (CO)	$\rho = 1.25$ g/l
Carbon dioxide (CO_2)	$\rho = 1.964$ g/l
Hydrocarbons:	
for petrol (E0) ($C_1H_{1.85}$)	$\rho = 0.619$ g/l
for petrol (E5) ($C_1H_{1.89}O_{0.016}$)	$\rho = 0.632$ g/l
for petrol (E10) ($C_1H_{1.93}\ O_{0.033}$)	$\rho = 0.646$ g/l
for diesel (B0) ($C_1H_{1.86}$)	$\rho = 0.620$ g/l
for diesel (B5) ($C_1H_{1.86}O_{0.005}$)	$\rho = 0.623$ g/l
for diesel (B7) ($C_1H_{1.86}O_{0.007}$)	$\rho = 0.625$ g/l
for LPG ($C_1H_{2.525}$)	$\rho = 0.649$ g/l
for NG/biomethane (CH_4)	$\rho = 0.716$ g/l
for ethanol (E85) ($C_1H_{2.74}O_{0.385}$)	$\rho = 0.934$ g/l
Nitrogen oxides (NO_x)	$\rho = 2.05$ g/l
Nitrogen dioxide (NO_2)	$\rho = 2.05$ g/l
Nitrous oxide (N_2O)	$\rho = 1.964$ g/l

The density for NMHC mass calculations shall be equal to that of total hydrocarbons at 273.15 K (0 °C) and 101.325 kPa and is fuel-dependent. The density for propane mass calculations (see paragraph 3.5. in Annex 5) is 1.967 g/l at standard conditions.

If a fuel type is not listed above, the density of that fuel shall be calculated using the equation described in paragraph 3.1.3. below.

3.1.3. The general equation for the calculation of total hydrocarbon density for each reference fuel with an average composition of $C_XH_YO_Z$ is as follows:

$$\rho_{THC} = \frac{MW_c + \frac{H}{C} \times MW_H + \frac{O}{C} \times MW_O}{V_M} \quad (4)$$

where:

ρ_{THC} is the density of total hydrocarbons and non-methane hydrocarbons, g/l;

MW_C is the molar weight of carbon (12.011 g/mol);

MW_H is the molar weight of hydrogen (1.008 g/mol);

MW_O is the molar weight of oxygen (15.999 g/mol);

V_M is the molar volume of an ideal gas at 273.15 K (0° C) and 101.325 kPa (22.413 l/mol);

H/C is the hydrogen to carbon ratio for a specific fuel $C_XH_YO_Z$;

O/C is the oxygen to carbon ratio for a specific fuel $C_XH_YO_Z$.

3.2. Mass emissions calculation

3.2.1. Mass emissions of gaseous compounds per test and per phase shall be calculated using the following equations:

If the number of phases, n, per test is 1, M_i per test shall be calculated as follows:

$$M_{i,test} = \frac{V_{mix,test} \times \rho_i \times KH_{test} \times C_{i,test} \times 10^{-6}}{d_{test}} \quad (5a)$$

If the number of phases, n, per test is >1, M_i per test shall be calculated as follows:

$$M_{i,phase} = \frac{V_{mix,phase} \times \rho_i \times KH_{phase} \times C_{i,phase} \times 10^{-6}}{d_{phase}} \quad (5b)$$

$$M_{i,test} = \frac{\sum_{phase=1}^{n} (M_{i,phase} \times d_{phase})}{\sum_{phase=1}^{n} d_{phase}} \quad (5c)$$

(In this case V_{mix}, KH, c_i, and d of the corresponding phase shall be used.)

where:

M_i is the mass emission of compound i per test or phase, g/km;

V_{mix} is the volume of the diluted exhaust gas per test or phase expressed in litres per test/phase and corrected to standard conditions (273.15 K (0 °C) and 101.325 kPa);

ρ_i is the density of compound i in grams per litre at standard temperature and pressure (273.15 K (0 °C) 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) per test or phase;

C_i is the concentration of compound i per test or phase in the diluted exhaust gas expressed in ppm and corrected by the amount of compound (i) contained in the dilution air;

d is the distance driven over the corresponding WLTC, km;

n is the number of phases of the corresponding WLTC..

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:

$$C_i = C_e - C_d \times \left(1 - \frac{1}{DF}\right) \quad (6)$$

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 dilution air, ppm;

DF is the dilution factor.

3.2.1.1.1. The dilution factor, DF, shall be calculated as follows:

$$DF = \frac{13.4}{C_{CO2}+(C_{HC}+C_{CO})\times 10^{-4}} \quad \text{for petrol (E0, E5, E10) and diesel (B0)} \quad (7a)$$

$$DF = \frac{13.5}{C_{CO2}+(C_{HC}+C_{CO})\times 10^{-4}} \quad \text{for diesel (B5 and B7)} \quad (7b)$$

$$DF = \frac{11.9}{C_{CO2}+(C_{HC}+C_{CO})\times 10^{-4}} \quad \text{for LPG} \quad (7c)$$

$$DF = \frac{9.5}{C_{CO2}+(C_{HC}+C_{CO})\times 10^{-4}} \quad \text{for NG/biomethane} \quad (7d)$$

$$DF = \frac{12.5}{C_{CO2}+(C_{HC}+C_{CO})\times 10^{-4}} \quad \text{for ethanol (E85)} \quad (7e)$$

$$DF = \frac{35.03}{C_{H2O}-C_{H2O-DF}+C_{H2}\times 10^{-4}} \quad \text{for hydrogen} \quad (7f)$$

If a fuel type is not listed above, the DF for that fuel shall be calculated using the equations in paragraph 3.2.1.1.2. below.

If the manufacturer uses a DF which covers several phases, it shall calculate a DF using the average concentration of gaseous compounds for the phases concerned.

The average concentration of a gaseous compound shall be calculated by dividing the sum of the product of the concentration of each phase times its V_{mix} by the sum of each phase's V_{mix}.

Comment [SMD98]: CONFIRMATION: March 2015 drafting meeting.

Comment [SMD99]: EXPERT PROPOSAL: April 2015 drafting meeting, Stockholm. Proposal from Fujiwara-san.

3.2.1.1.2. The general equation for calculating the dilution factor , DF, for each reference fuel with an average composition of $C_xH_yO_z$ is as follows:

$$DF = \frac{X}{C_{CO2}+(C_{HC}+C_{CO})\times 10^{-4}} \quad (8)$$

where:

$$X = 100 \times \frac{x}{x+\frac{y}{2}+3.76\left(x+\frac{y}{4}-\frac{z}{2}\right)} \quad (9)$$

:

C_{CO2} is the concentration of CO_2 in the diluted exhaust gas contained in the sample bag, per cent volume;

C_{HC} is the concentration of HC in the diluted exhaust gas contained in the sample bag, ppm carbon equivalent;

C_{CO} is the concentration of CO in the diluted exhaust gas contained in the sample bag, ppm.

3.2.1.1.3. Methane measurement

3.2.1.1.3.1. For methane measurement using a GC-FID, NMHC shall be calculated as follows:

$$C_{NMHC} = C_{THC} - (Rf_{CH4} \times C_{CH4}) \quad (10)$$

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 CH4 in the diluted exhaust gas, ppm carbon equivalent and corrected by the amount of CH4 contained in the dilution air;

Rf_{CH4} is the FID response factor to methane as defined in paragraph 5.4.3.2. of Annex 5.

3.2.1.1.3.2. For methane measurement using an 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;

(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:

$$C_{CH4} = \frac{C_{HC(w/NMC)} - C_{HC(w/oNMC)} \times (1 - E_E)}{r_h \times (E_E - E_M)} \quad (11)$$

$$C_{NMHC} = \frac{C_{HC(w/oNMC)} \times (1 - E_M) - C_{HC(w/NMC)}}{E_E - E_M} \quad (12)$$

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

$$C_{CH4} = \frac{C_{HC(w/NMC)} \times r_h \times (1 - E_M) - C_{HC(w/oNMC)} \times (1 - E_E)}{r_h \times (E_E - E_M)} \quad (13)$$

$$C_{NMHC} = \frac{C_{HC(w/oNMC)} \times (1 - E_M) - C_{HC(w/NMC)} \times r_h \times (1 - E_M)}{E_E - E_M} \quad (14)$$

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 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 11, 13 and 14.

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:

$$E_M = 1 - \frac{C_{HC(w/NMC)}}{C_{HC(w/oNMC)}} \quad (15)$$

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, E_E

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:

$$E_E = 1 - \frac{C_{HC(w/NMC)}}{C_{HC(w/oNMC)}} \quad (16)$$

where:

$C_{HC(w/NMC)}$ 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, 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 13 from above becomes:

$$C_{CH4} = C_{HC(w/NMC)} \quad (17)$$

Equation 14 from above becomes:

$$C_{NMHC} = C_{HC(w/oNMC)} - C_{HC(w/NMC)} \times r_h \quad (18)$$

The density used for NMHC mass calculations shall be equal to that of total hydrocarbons at 273.15 K (0 °C) 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 Annex 5.

When the CVS flow rate, q_{VCVS}, over the test varies by more than ± 3 per cent of the average flow rate, a flow-weighted average shall be used for all continuous diluted measurements including PN:

$$C_e = \frac{\sum_{i=1}^{n} q_{VCVS}(i) \times \Delta t \times C(i)}{V} \quad (19)$$

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:

$$KH = \frac{1}{1 - 0.0329 \times (H - 10.71)} \quad (20)$$

where:

$$H = \frac{6.211 \times R_a \times P_d}{P_B - P_d \times R_a \times 10^{-2}} \quad (21)$$

and:

H is the specific humidity, grams of water vapour per kilogram 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;

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 shall be 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:

$$C_e = \frac{\int_{t_1}^{t_2} C_{NO}\,dt}{t_2 - t_1} \quad (22)$$

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 shall be determined from the dilution air bag. A correction shall be carried out according to paragraph 3.2.1.1. of this 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 shall be calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{NO_2}\,dt}{t_2 - t_1} \quad (23)$$

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 shall be determined from the dilution air bags. Correction is carried out according to paragraph 3.2.1.1. of this 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:

$$C_e = \frac{\int_{t_1}^{t_2} C_{HC}\,dt}{t_2 - t_1} \quad (24)$$

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 Annex.

3.2.3. Fuel consumption and CO_2 calculations for individual vehicles in an interpolation family

3.2.3.1. Fuel consumption and CO_2 emissions without using the interpolation method

The CO_2 value, as calculated in paragraph 3.2.1. above and FC, as calculated according to paragraph 6 of this Annex, shall be attributed to all individual vehicles in the interpolation family and the CO_2 interpolation method shall not be applicable.3.2.3.2. Fuel consumption and CO_2 emissions using the interpolation method

The CO_2 emissions and the fuel consumption for each individual vehicle in the interpolation family may be calculated according to the CO_2 interpolation method outlined in paragraphs 3.2.3.2.1. to 3.2.3.2.5. inclusive. 3.2.3.2.1. Determination of fuel consumption and CO_2 emissions of test vehicles L and H

The mass of CO_2 emissions, M_{CO_2}, of test vehicles L and H shall be determined according to the calculations in paragraph 3.2.1. above for the individual cycle phases p of the applicable WLTC and are referred to as $M_{CO_2-L,p}$ and $M_{CO_2-H,p}$ respectively. Fuel consumption for individual cycle phases of the applicable WLTC shall be determined according to paragraph 6 of this Annex and are referred to as $FC_{L,p}$ and $FC_{H,p}$ respectively.

3.2.3.2.2. Road load calculation for an individual vehicle

3.2.3.2.2.1. Mass of an individual vehicle

The test masses of vehicles H and L shall be used as input for the interpolation method.

TM_{ind} ,in kg, shall be the individual test mass of the vehicle according to paragraph XXX [to be determined: "test mass of the vehicle"] of II. text of the global technical regulation.

Comment [SMD100]: OPEN POINT: 22.04.2015. Enter the proper paragraph number once all definitions are re-numbered.

If the same test mass is used for test vehicles L and H, the value of TM_{ind} shall be set to the mass of test vehicle H for the interpolation method.

3.2.3.2.2.2. Rolling resistance of an individual vehicle

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. See Annex 4, paragraph 4.2.2.1.

If the tyres on the front and rear axles of vehicle L or H have different rolling resistance values, the weighted average of the rolling resistances shall be calculated using the following equation:

$$RR_x = RR_{x,FA} * mp_{x,FA} + RR_{x,RA} * (1 - mp_{x,FA}) \quad (25)$$

where:

$RR_{x,FA}$ is the rolling resistance of the front axle tyres, kg/tonne;

$RR_{x,RA}$ is the rolling resistance of the rear axle tyres, kg/tonne;

$mp_{x,FA}$ is the percentage of the vehicle mass on the front axle;

x represents vehicle L, H or an individual vehicle.

For the tyres fitted to an 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 Annex 4.

If the tyres have different rolling resistance class values on the front and the rear axle, the weighted average shall be used, calculated with the equation above.

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 an individual vehicle

The aerodynamic drag shall be measured for each of the drag-influencing options and body shapes in a wind tunnel fulfilling the requirements of paragraph 3.2. of Annex 4 verified by the responsible authority. Any aerodynamic differences, $\Delta(C_D \times A_f)$, between vehicles L, H and/or an individual vehicle shall be determined with an accuracy of 0.015 m².

$\Delta(C_D \times A_f)$ may be calculated according to the following equation maintaining the accuracy of 0.015 m² also for the sum of options and body shapes:

$$\Delta(C_D \times A_f)_{ind} = \sum_{i=1}^{n} \Delta(C_D \times A_f)_i \quad (26)$$

where:

C_D is the aerodynamic drag coefficient;

A_f is the frontal area of the vehicle, m^2;

n is the number of options on the vehicle that are different between an individual vehicle and test vehicle L.

$\Delta(C_D \times A_f)_{ind}$ is the difference in aerodynamic drag between an individual vehicle and test vehicle L due to options on the vehicle that differ from those installed on test vehicle L, m^2;

$\Delta(C_d \times A_f)_i$ is the difference in aerodynamic drag due to an individual feature, i, on the vehicle and is positive for an option that adds aerodynamic drag with respect to test vehicle L and vice versa, m^2;

The sum of all $\Delta(C_D \times A_f)_i$ different between test vehicles L and H shall correspond to the total difference between test vehicles L and H and is referred to as $\Delta(C_D \times A_f)_{LH}$.

Comment [SMD101]: OPEN POINT: 12.05.2015: This is basically the same as the last sentence in this paragraph (see the box labelled 12.05.2015)

The increase or decrease of the aerodynamic drag expressed as $\Delta(C_D \times A_f)$ for all of the optional equipment and body shapes in the interpolation family which:

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

(b) is to be included in the interpolation,

shall be recorded.

The aerodynamic drag of vehicle H shall be applied to the whole interpolation family and $\Delta(C_D{*}A_f)_{LH}$, defined below, shall be set to zero, if:

(a) the wind tunnel facility is not able to accurately determine $\Delta(C_D{*}A_f)$;

(b) there are no drag influencing options between the test vehicles H and L that shall be included in the interpolation method.

$\Delta(C_D{*}A_f)_{LH}$, m², is the difference in aerodynamic drag of the test vehicle H compared to test vehicle L and shall be recorded.

Comment [SMD102]: OPEN POINT: 12.05.2015: Is this necessary, as it repeats what is stated (see comment above dated 12.05.2015)

3.2.3.2.2.4. Calculation of road load for individual vehicles in the CO_2 interpolation family

The road load coefficients f_0, f_1 and f_2 (as defined in Annex 4) for 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:

$$F_L(v) = f^*_{0,L} + f_{1,H} \times v + f^*_{2,L} \times v^2 \quad (27)$$

Applying the least squares regression method in the range of the reference speed points, 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 an individual vehicle in the CO_2 interpolation family are calculated as follows:

$$f_{0,ind} = f_{0,H} - \Delta f_0 \times \frac{(TM_H \times RR_H - TM_{ind} \times RR_{ind})}{(TM_H \times RR_H - TM_L \times RR_L)} \quad (28)$$

or, if $(TM_H \times RR_H - TM_L \times RR_L) = 0$, equation 29 below shall apply:

$$f_{0,ind} = f_{0,H} - \Delta f_0 \quad (29)$$

$$f_{1,ind} = f_{1,H} \quad (30)$$

$$f_{2,ind} = f_{2,H} - \Delta f_2 \frac{(\Delta[C_d \times A_f]_{LH} - \Delta[C_d \times A_f]_{ind})}{(\Delta[C_d \times A_f]_{LH})} \quad (31)$$

or, if $\Delta(C_d \times A_f)LH = 0$, equation 32 below shall apply:

$$f_{2,ind} = f_{2,H} - \Delta f_2 \quad (32)$$

where:

$$\Delta f_0 = f_{0,H} - f^*_{0,L} \quad (33)$$

$$\Delta f_2 = f_{2,H} - f^*_{2,L} \quad (34)$$

3.2.3.2.3. 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 interpolation family shall be calculated according to the procedure in paragraph 5. of this Annex, for the following sets k of road load coefficients and masses:

k=1: $f_0 = f^*_{0,L},\ f_1 = f_{1,H},\ f_2 = f^*_{2,L},\ m = TM_L$ (35)

(test vehicle L)

k=2: $f_0 = f_{0,H},\ f_1 = f_{1,H},\ f_2 = f_{2,H},\ m = TM_H$ (36)

(test vehicle H)

k=3: $f_0 = f_{0,ind},\ f_1 = f_{1,H},\ f_2 = f_{2,ind},\ m = TM_{ind}$ (37)

(an individual vehicle in the CO_2 interpolation family)

3.2.3.2.4..3.. Calculation of the CO_2 value for an individual vehicle using the CO_2 interpolation method

For each cycle phase, p, of the WLTC applicable for individual vehicles in the CO_2 interpolationfamily, the contribution to the total mass of CO_2 for an individual vehicle shall be calculated as follows:

$$M_{CO_2-ind,p} = M_{CO_2-L,p} + \left(\frac{E_{3,p}-E_{1,p}}{E_{2,p}-E_{1,p}}\right) \times \left(M_{CO_2-H,p} - M_{CO_2-L,p}\right) \quad (38)$$

The terms $E_{1,p}$, $E_{2,p}$ and $E_{3,p}$ are defined in paragraph 3.2.3.2.3. above.

The CO_2 mass emissions attributed to an individual vehicle of the CO_2 interpolation family, M_{CO_2-ind}, shall be calculated by the following equation for all of the applicable cycle phases, p:

$$M_{CO_2-ind} = \frac{\sum_p M_{CO_2-ind,p} \times d_{c,p}}{\sum_p d_{c,p}} \quad (39)$$

3.2.3.2.5. Calculation of the fuel consumption, FC, value for an individual vehicle using the energy interpolation method

For each cycle phase p of the WLTC applicable for individual vehicles in the CO_2 interpolation family, the contribution to the FC for an individual vehicle shall be calculated as follows:

$$FC_{ind,p} = FC_{L,p} + \left(\frac{E_{3,p}-E_{1,p}}{E_{2,p}-E_{1,p}}\right) \times \left(FC_{H,p} - FC_{L,p}\right)$$

The terms $E_{1,p}$, $E_{2,p}$ and $E_{3,p}$ are defined in paragraph 3.2.3.2.3. above.

The fuel consumption, $FC_{ind,}$ attributed to an individual vehicle of the CO_2 interpolation family, FC_{ind}, shall be calculated for all applicable cycle phases using the following equation:

$$FC_{ind} = \frac{\sum_p FC_{ind,p} \times d_{c,p}}{\sum_p d_{c,p}} \quad .$$

3.3 Mass of particulate emissions

3.3.1. Calculation of particulate emissions

Particulate emission M_p (g/km) is calculated as follows:

$$M_p = \frac{(V_{mix}+V_{ep}) \times P_e}{V_{ep} \times d} \quad (40)$$

where exhaust gases are vented outside tunnel;

and:

$$M_p = \frac{V_{mix} \times P_e}{V_{ep} \times d} \quad (41)$$

where exhaust gases are returned to the tunnel;

where:

V_{mix} is the volume of diluted exhaust gases (see paragraph 2. of this 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 mass of particulate matter collected by one or more filters, mg;

d is the distance corresponding to the operating cycle, km.

Comment [SMD103]: GTR CORRECTION: April 2015 drafting meeting, Stockholm. Why is FCind here twice?
Secondly, should the phrase "for all applicable cycle phases" not go to the start of the sentence?

Comment [SMD104]: GTR CORRECTION: 29.03.2015. An equation number will be required here.

3.3.1.1. Where correction for the PM background level from the dilution system has been used, this shall be determined in accordance with paragraph 1.2.1.3.1. of Annex 6. In this case, PM (mg/km) shall be calculated as follows:

$$M_p = \left\{\frac{P_e}{V_{ep}} - \left[\frac{P_a}{V_{ap}} \times \left(1 - \frac{1}{DF}\right)\right]\right\} \times \frac{(V_{mix}+V_{ep})}{d} \quad (42)$$

in the case where exhaust gases are vented outside tunnel;

$$M_p = \left\{\frac{P_e}{V_{ep}} - \left[\frac{P_a}{V_{ap}} \times \left(1 - \frac{1}{DF}\right)\right]\right\} \times \frac{(V_{mix})}{d} \quad (43)$$

in the case where exhaust gases are returned to the tunnel;

where:

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 Annex 6; ;

DF is the dilution factor determined in paragraph 3.2.1.1.1. of this Annex.

Where application of a background correction results in a negative result, it shall be considered to be zero mg/km.

3.3.2. Calculation of PM using the double dilution method

$$V_{ep} = V_{set} - V_{ssd} \quad (44)$$

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 under standard conditions;

V_{ssd} is the volume of the secondary dilution air under standard conditions.

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.:

$$V_{mix} = V_{mix\ indicated} + V_{ep} \quad (45)$$

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

Comment [SMD105]: GTR CORRECTION: April 2015 drafting meeting, Stockholm. More consistence in the use of particle number.

4.1. The number of particle emissions shall be calculated by means of the following equation:

$$N = \frac{V \times k \times (\overline{C_s} \times \overline{f_r} - C_b \times \overline{f_{rb}}) \times 10^3}{d} \quad (46)$$

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 (0 °C) 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 cycle. If the volumetric mean concentration results, $\bar{C}$, from the particle number counter are not measured at standard conditions (273.15 K (0 °C) and 101.325 kPa), the concentrations shall be corrected to those conditions, $\overline{C_s}$;

C_b is either the dilution air or the dilution tunnel background particle concentration, as permitted by the responsible authority, in particles per cubic centimeter, corrected for coincidence and to standard conditions (273.15 K (0 °C) and 101.325 kPa);

$\overline{f_r}$ is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the test;

$\overline{f_{rb}}$ 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:

$$\bar{C} = \frac{\sum_{i=1}^{n} C_i}{n} \quad (47)$$

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:

$$n = t \times f \quad (48)$$

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

Unless otherwise specified, the calculation shall be based on the target speed trace given in discrete time sample points.

For the calculation, each time sample point shall be interpreted as a time period. Unless otherwise specified, the duration Δt of these periods shall be 1 second.

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:

$$E = \sum_{t_{start}}^{t_{end}} E_i \quad (49)$$

where:

$$E_i = F_i \times d_i \quad \text{if } F_i > 0 \quad (50)$$

$$E_i = 0 \quad \text{if } F_i \leq 0 \quad (51)$$

and:

t_{start} is the time at which the applicable cycle or phase starts, s;

t_{end} is the time at which the applicable cycle or phase ends, s;

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.

$$F_i = f_0 + f_1 \times \left(\frac{v_i + v_{i-1}}{2}\right) + f_2 \times \frac{(v_i + v_{i-1})^2}{4} + (1.03 \times TM) \times a_i \quad (52)$$

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_Hor TM_{ind}) in N, N/km/h and in N/(km/h)² respectively.

$$d_i = \frac{(v_i + v_{i-1})}{2 \times 3.6} \times (t_i - t_{i-1}) \quad (53)$$

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.

$$a_i = \frac{v_i - v_{i-1}}{3.6 \times (t_i - t_{i-1})} \quad (54)$$

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 Annex 3 in this gtr.

Comment [SMD106]: OPEN POINT: 17.03.2015. Hydrogen yet to be added. Tom Adam will contact drafting co.

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 gtr.

6.2.1. The general equation in paragraph 6.12. using H/C and O/C ratios shall be used for the calculation of fuel consumption.6.3. For a vehicle with a positive ignition engine fuelled with petrol (E0)

$$FC = \left(\frac{0.1155}{\rho}\right) \times [(0.866 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55a)$$

6.4. For a vehicle with a positive ignition engine fuelled with petrol (E5)

$$FC = \left(\frac{0.118}{\rho}\right) \times [(0.848 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55b)$$

6.5. For a vehicle with a positive ignition engine fuelled with petrol (E10)

$$FC = \left(\frac{0.1206}{\rho}\right) \times [(0.829 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55c)$$

6.6. For a vehicle with a positive ignition engine fuelled with LPG

$$FC_{norm} = \left(\frac{0.1212}{0.538}\right) \times [(0.825 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55d)$$

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:

$$FC_{norm} = \left(\frac{0.1212}{0.538}\right) \times cf \times [(0.825 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55e)$$

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

$$cf = 0.825 + 0.0693 \times n_{actual} \quad (55f)$$

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

$$FC_{norm} = \left(\frac{0.1336}{0.654}\right) \times [(0.749 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55g)$$

6.8. For a vehicle with a compression engine fuelled with diesel (B0)

$$FC = \left(\frac{0.1156}{\rho}\right) \times [(0.865 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55h)$$

6.9. For a vehicle with a compression engine fuelled with diesel (B5)

$$FC = \left(\frac{0.1163}{\rho}\right) \times [(0.860 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55i)$$

6.10. For a vehicle with a compression engine fuelled with diesel (B7)

$$FC = \left(\frac{0.1165}{\rho}\right) \times [(0.858 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55j)$$

6.11. For a vehicle with a positive ignition engine fuelled with ethanol (E85)

$$FC = \left(\frac{0.1743}{\rho}\right) \times [(0.574 \times HC) + (0.429 \times CO) + (0.273 \times CO_2)] \quad (55k)$$

;

6.12. Fuel consumption for any test fuel may be calculated using the following equation:

$$FC = \frac{MW_C + \frac{H}{C} \times MW_H + \frac{O}{C} \times MW_O}{MW_C \times \rho_{fuel} \times 10} \times \left(\frac{MW_C}{MW_C + \frac{H}{C} \times MW_H + \frac{O}{C} \times MW_O} \times HC + \frac{MW_C}{MW_{CO}} \times CO + \frac{MW_C}{MW_{CO_2}} \times CO_2\right) \quad (56)$$

6.13. Fuel consumption for vehicles fuelled by gaseous hydrogen:

$$FC = 0.024 \times \frac{V}{d} \times \left(\frac{1}{Z_1} \times \frac{p_1}{T_1} - \frac{1}{Z_2} \times \frac{p_2}{T_2}\right) \quad (57)$$

With approval of the responsible authority and for vehicles fuelled either with gaseous or liquid hydrogen, the manufacturer may choose to calculate fuel consumption using either the equation below or a method using a standard protocol such as SAE J2572.

$$FC = 0.1 \times (0.1119 \times H_2O + H_2) \quad (58)$$

The compressibility factor, Z, shall be obtained from the following table:

		T (K)									
		5	100	200	300	400	500	600	700	800	900
p (bar)	33	0.859	1.051	1.885	2.648	3.365	4.051	4.712	5.352	5.973	6.576
	53	0.965	0.922	1.416	1.891	2.338	2.765	3.174	3.57	3.954	4.329
	73	0.989	0.991	1.278	1.604	1.923	2.229	2.525	2.810	3.088	3.358
	93	0.997	1.042	1.233	1.470	1.711	1.947	2.177	2.400	2.617	2.829
	113	1.000	1.066	1.213	1.395	1.586	1.776	1.963	2.146	2.324	2.498
	133	1.002	1.076	1.199	1.347	1.504	1.662	1.819	1.973	2.124	2.271
	153	1.003	1.079	1.187	1.312	1.445	1.580	1.715	1.848	1.979	2.107
	173	1.003	1.079	1.176	1.285	1.401	1.518	1.636	1.753	1.868	1.981
	193	1.003	1.077	1.165	1.263	1.365	1.469	1.574	1.678	1.781	1.882
	213	1.003	1.071	1.147	1.228	1.311	1.396	1.482	1.567	1.652	1.735
	233	1.004	1.071	1.148	1.228	1.312	1.397	1.482	1.568	1.652	1.736
	248	1.003	1.069	1.141	1.217	1.296	1.375	1.455	1.535	1.614	1.693
	263	1.003	1.066	1.136	1.207	1.281	1.356	1.431	1.506	1.581	1.655
	278	1.003	1.064	1.130	1.198	1.268	1.339	1.409	1.480	1.551	1.621
	293	1.003	1.062	1.125	1.190	1.256	1.323	1.390	1.457	1.524	1.590
	308	1.003	1.060	1.120	1.182	1.245	1.308	1.372	1.436	1.499	1.562
	323	1.003	1.057	1.116	1.175	1.235	1.295	1.356	1.417	1.477	1.537
	338	1.003	1.055	1.111	1.168	1.225	1.283	1.341	1.399	1.457	1.514
	353	1.003	1.054	1.107	1.162	1.217	1.272	1.327	1.383	1.438	1.493

For all equations in paragraph 6:

FC is the fuel consumption of a specific fuel, l/100 km (or m³ per 100 km in the case of natural gas or kg/100 km in the case of hydrogen);

H/C is the hydrogen to carbon ratio of a specific fuel $C_XH_YO_Z$;

O/C is the oxygen to carbon ratio of a specific fuel $C_XH_YO_Z$;

MW_C is the molar weight of carbon (12.011 g/mol);

MW_H is the molar weight of hydrogen (1.008 g/mol);

MW_O is the molar weight of oxygen (15.999 g/mol);

ρ_{fuel} is the test fuel density, kg/l. For gaseous fuels, fuel density at 15 °C;

HC are the measured emissions of hydrocarbon, 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 are the measured emissions of water, g/km;

H_2 are the measured emissions of hydrogen, g/km;

p_1 is the gas pressure in the fuel tank before the operating cycle, Pa;

p_2 is the gas pressure in the fuel tank after the operating cycle, Pa;

T_1 is the gas temperature in the fuel tank before the operating cycle, K;

T_2 is the gas temperature in the fuel tank after the operating cycle, K;

Z_1 is the compressibility factor of the gaseous fuel at p_1 and T_1;

Z_2 is the compressibility factor of the gaseous fuel at p_2 and T_2;

V is the interior volume of the gaseous fuel tank, m^3.

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 Annex replaces Appendix 2 of 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 Annex 5.

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 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 ($Extra\ High_3$).

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

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 $High_3$).

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 $High_3$).

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

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 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra $High_3$)	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra $High_3$)	Low_3 + $Medium_{3-1}$
	Class 3b	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra $High_3$)	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra $High_3$)	Low_3 + $Medium_{3-2}$
NOVC-HEV	Class 3a	--	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra $High_3$)	--
	Class 3b	--	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra $High_3$)	--
PEV	Class 3a	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra $High_3$)	--	Low_3 + $Medium_{3-1}$
	Class 3b	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra $High_3$)	--	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 Annex 6, the vehicles tested to this 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

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 Annex 6 to this gtr unless modified by this 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 at the 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 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 Annex.

3.2.2. Vehicles may be tested according to four possible test sequences:

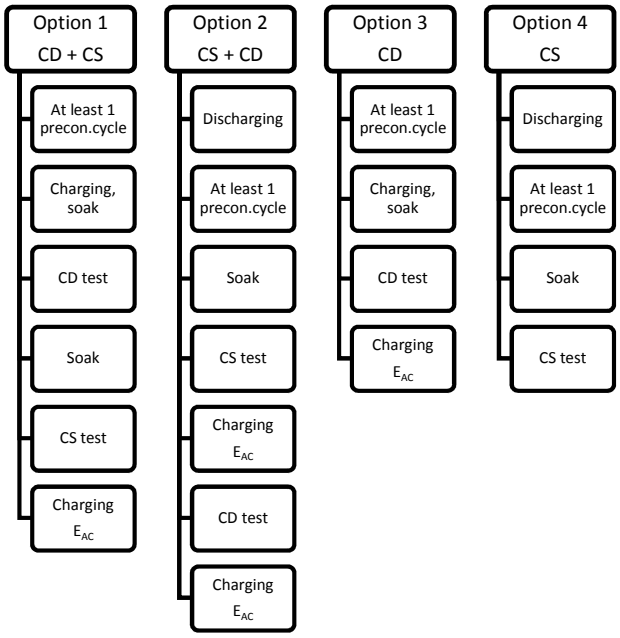
3.2.2.1. Option 1: charge-depleting test with a subsequent charge-sustaining test (CD + CS test).

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).

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. CD test with no subsequent CS test (option 3)

3.2.4.1. Preconditioning

The vehicle shall be prepared according to the procedures in Appendix 4, paragraph 2.2. of this 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 Annex.

3.2.4.2.2. Operation mode selection

3.2.4.2.2.1. The ~~charge-depleting~~CD test shall be performed in the highest electric energy consumption mode that best matches the driving cycle.~~by using the most electric energy consuming mode that 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~~CD condition testing.

Comment [SMD107]: GTR CORRECTION: 27.11.2014: It has been requested that this be written as it is open to interpretation and/or is not robust enough.

Comment [SMD108]: GTR CORRECTION: 02.04.2015. Has the paragraph been rewritten?

3.2.4.3. Type 1 test procedure

3.2.4.3.1. The CD test procedure shall consist of a number of consecutive cycles, each followed by a soak period of no more than 30 minutes until CS operation is achieved.

3.2.4.3.2. During soaking between individual WLTCs, the ~~key~~ ignition switch shall be in the "OFF~~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 Annex 5 and without prejudice to paragraph 5.3.1.2., analysers may be calibrated and zero checked before and after the CD test.

3.2.4.4. End of the CD test

The end of the CD 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 CS 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 CD test is reached when the relative net energy change, NEC, as shown in the equation below is less than 4 per cent.

$$\text{NEC}\ (\%) = \left(\frac{\text{RCB} \times \text{nominal REESS voltage}}{\text{test vehicle cycle energy demand}}\right) < 4\ \%\qquad (1)$$

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 CD 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.

3.2.4.7. Each individual full WLTC within the CD test shall fulfil the applicable exhaust emission limits according to paragraph 1.1.1.2. of Annex 6.

Comment [SMD109]: GTR CORRECTION: 02.05.2015: DC proposes that “ignition” be maintained as the term does not necessarily imply something leading to combustion but to energising or switching on an electrical system.

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 Annex.

3.2.5.2. Test conditions

3.2.5.2.1. Tests shall be carried out with the vehicle operated in CS 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 CS 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.

3.2.5.2.4. Upon request of the manufacturer and with approval of the responsible authority, the manufacturer may set the start state of charge of the traction REESS for the CS test.

3.2.5.3. Type 1 test procedure

3.2.5.3.1. If required by paragraph 4.2.1.3. of this Annex, CO_2, emissions and fuel consumption results shall be corrected according to the RCB correction as described in Appendix 2 of this Annex.

3.2.5.3.2. The CS test shall fulfil the applicable exhaust emission limits according to paragraph 1.1.1.2. of 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. to 3.2.4.5. inclusive of this Annex shall be followed.

3.2.6.2. Subsequently, the procedures for the CS test from paragraphs 3.2.5.1. to 3.2.5.3. inclusive (except paragraph 3.2.5.2.4.) in this 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 CS 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)

3.2.7.1. The procedures for the CS test from paragraphs 3.2.5.1. to 3.2.5.3. inclusive, and paragraph 3.2.6.3. in this Annex shall be followed.

3.2.7.2. Subsequently, the procedures for the CD test from paragraphs 3.2.4.3. to 3.2.4.7. inclusive of this 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 Annex 7.

3.2.9. Electric range determination

3.2.9.1. The CD test procedure as described in paragraph 3.2.4. of this 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 CD test to the point in time during the test when the combustion engine starts to consume fuel shall be measured.

3.2.9.2.2. At the option of the Contracting Party, the determination of AERcity may be excluded.

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 CD 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.

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 CS conditions according to the cycles described in paragraph 1.5.1.2.1. of this 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 CS test may be set according to manufacturer's recommendation in order to achieve a charge balance neutral CS test.

3.3.3. Type 1 Test

3.3.3.1. If required by paragraph 4.2.2. of this Annex, CO_2 emissions and fuel consumption results shall be corrected according to the RCB correction described in Appendix 2 to this Annex.

3.4. PEV, with and without driver-selectable operating mode

3.4.1. Vehicles shall be tested under CD conditions according to the cycles described in paragraph 1.5.1.1. of this Annex.

3.4.2. The total distance travelled over the test cycles from the beginning of the CD test until the break-off criterion is reached shall be recorded.

3.4.3. Breaks for the driver and/or operator shall be permitted only between test cycles as described in Table A8/4.

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 CD 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;

(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 Annex.

3.4.4.3.1.2. WLTCs shall be driven and the AER distance shall be measured.

3.4.4.3.1.3. The end of the test occurs when the break-off criterion is reached.

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.

3.4.4.3.1.4. The vehicle shall be connected to the mains within 120 minutes after the conclusion of the AER determination. 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 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 of this Annex. ~~The initial charging procedure of the traction REESS shall start with a normal charging and the end of charge criteria shall be as defined in paragraph 3.4.4.3.1.5. above and in Appendix 4 of this Annex.~~

3.4.4.4.1.2. City cycles shall be driven and the 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 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-sustaining mode emissions

4.1.1.1.1. The charging balance correction (RCB) calculation is not required for the determination of emissions compounds.

4.1.1.2. Weighted emissions compounds

The weighted emissions compounds, $M_{i,weighted}$, from the CD and CS test results shall be calculated using the equation below:

$$M_{i,weighted} = \sum_{j=1}^{k}(UF_j \times M_{i,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) \times M_{i,CS} \quad (2)$$

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} CD phase, g/km;

$M_{i,CS}$ are the compound mass emissions for the CS 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 Annex 7.

Comment [SMD110]:

Comment [SMD111]: 11.05.2014: Modification to 3.4.4.4.1.1. provided by P. Öhlund.

Comment [SMD112]:

Comment [SMD113]: OPEN POINT: 02.04.2015. Still an open point?

4.1.2.2. The charging balance correction (RCB) calculation is not required for the determination of emission compounds.

4.2. CO_2 and fuel consumption calculations

Exhaust gases shall be analysed according to 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:

$$CO_{2,CD} = \sum_{j=1}^{k}(UF_j \times CO_{2,CD,j}) / \sum_{j=1}^{k} UF_j \quad (3)$$

where:

$CO_{2,CD}$ is the utility factor-adjusted mass of CO_2 emissions during CD mode, g/km;

$CO_{2,CD,j}$ are the CO_2 emissions measured during the j^{th} CD phase, g/km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this 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.

4.2.1.2. Weighted charge-depleting fuel consumption

The fuel consumption values, FC_{CD}, at CD shall be calculated as follows:

$$FC_{CD} = \sum_{j=1}^{k}(UF_j \times FC_{CD,j}) / \sum_{j=1}^{k} UF_j \quad (4)$$

where:

FC_{CD} is the utility factor-adjusted fuel consumption CD mode, l/100 km;

$FC_{CD,j}$ is the fuel consumption measured during the j^{th} CD phase, l/100 km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this 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 Annex.

4.2.1.3.2. The electricity balance, measured using the procedure specified in Appendix 3 to this 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} if any of the following cases apply:

(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:

$$\Delta E_{REESS} = \frac{0.0036 \times RCB \times U_{REESS}}{E_{Fuel}} \times 100 \quad (5)$$

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~~Wh~~.

Comment [SMD114]: EXPERT PROPOSAL: 03.11.2014: proposal from Japan

ΔE_{REESS} is lower than or equal to the RCB correction criteria, according to the equation below and Table A8/5:

$$\Delta E_{REESS} \leq \text{RCB correction criterion}$$

Table A8/5
RCB Correction Criteria

Cycle	WLTC (Low + Medium + High)	WLTC (Low + Medium + High + Extra High)
RCB correction criterion (%)	1	0.5

4.2.1.4. Weighted CO_2 emissions

The weighted CO_2 emissions from the CD and CS test results shall be calculated using the equation below:

$$CO_{2,weighted} = \sum_{j=1}^{k}(UF_j \times CO_{2,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) \times CO_{2,CS} \quad (6)$$

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} CD phase, g/km;

$CO_{2,CS}$ are the CO_2 emissions for the CS 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;

k is the number of phases driven up to the end of transition cycle n.

4.2.1.5. Weighted fuel consumption

The weighted fuel consumption from the CD and CS test results shall be calculated using the equation below:

$$FC_{weighted} = \sum_{j=1}^{k}(UF_j \times FC_{CD,j}) + (1 - \sum_{j=1}^{k} UF_j) \times FC_{CS} \quad (7)$$

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} CD phase, l/100 km;

FC_{CS} is the fuel consumption measured during the CS 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 Annex 6.

4.2.2.2. CS fuel consumption and CO_2 emissions shall be calculated according to paragraph 4.2.1.3. of this 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 Annex.

4.2.2.3.1. The electricity balance, measured using the procedure specified in Appendix 3 to this 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.

$\Delta E_{REESS,}$ expressed as a percentage of the energy content of the fuel consumed over the cycle, shall be calculated using the equation below:

$$\Delta E_{REESS} = \frac{0.0036 \times \sum_{i=1}^{z} (RCB_i \times U_{REESSi})}{E_{fuel}} \times 100 \quad (8)$$

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 less than or equal to the RCB correction criteria, according to the following equation and Table A8/6 :

$$\Delta E_{REESS} \leq \text{RCB correction criterion}$$

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 Annex shall be used.

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:

$$EC_{weighted} = \sum_{j=1}^{k} (UF_j \times EC_{CD,j}) \quad (9)$$

$$EC_{CD,j} = \frac{RCB_j}{d_j * \sum_{j=1}^{k} RCB_j} \times E_{AC} \quad (10)$$

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 Annex;

$EC_{CD,j}$ is the calculated fraction of E_{AC} used in the j^{th} phase during the CD test, Wh/km;

RCB_j is the measured charge balance of the traction REESS of the j^{th} phase during the CD test, Ah;

d_j is the distance driven in the j^{th} phase during the CD test,km;

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;

k is the number of phases driven up to the end of transition cycle n.

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 recorded.

4.3.1.2.2. Electric energy consumption EC is defined by the equation:

$$EC = E_{AC}/EAER \quad (11)$$

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. CD AC electric energy consumption, EC_{CD}, including charging losses

$$EC_{CD} = \frac{EC_{weighted}}{\sum_{j=1}^{K} UF_j} \quad (12)$$

where:

EC_{CD} is the recharged electric energy from the grid including charging losses, Wh;

$EC_{weighted}$ is the electric energy consumption, Wh/km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this 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 recorded.

4.3.2.2. The electric energy consumption EC including charging losses is defined by the equation:

$$EC = E_{AC}/AER \quad (13)$$

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 Annex, km.

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. 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:

$$EAER = \left(\frac{CO_{2,CS} - CO_{2,CDavg}}{CO_{2,CS}}\right) \times R_{CDC} \quad (14)$$

where:

$$CO_{2,CD,avg} = \frac{\sum_{j=1}^{k} CO_{2,CD,j}}{\sum_{j=1}^{k} d_j} \quad (15)$$

and:

EAER is the equivalent all-electric range EAER, km;

$CO_{2,CS}$ are the CO_2 emissions during the CS test, g/km;

$CO_{2,CD,j}$ are the CO_2 emissions in the j^{th} phase during the CD test, g;

d_j is the distance driven in the j^{th} phase during the CD test, km;

R_{CDC} is the CD 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 CD 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 CD 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})

$$R_{CDA} = \sum_{j=1}^{n-1} d_{j,cycle} + \left(\frac{CO_{2,CS} - CO_{2,n,cycle}}{CO_{2,CS} - CO_{2,CD,average,n-1}}\right) \times d_n \quad (16)$$

where:

R_{CDA} is the actual CD range, km;

$CO_{2,CS}$ are the CO_2 emissions during the CS test, g/km;

$CO_{2,n,cycle}$	are the CO_2 emissions over the n^{th} drive cycle in CD operating condition, g/km;
$CO_{2,CD,average,n-1}$	are the average CO_2 emissions in CD operating condition until the n-1^{th} 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 CD 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.

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]

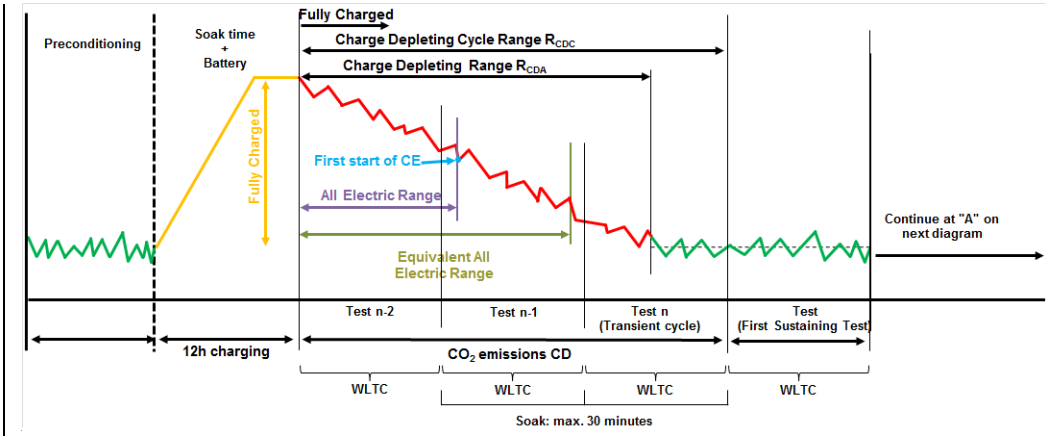
Annex 8 - Appendix 1a

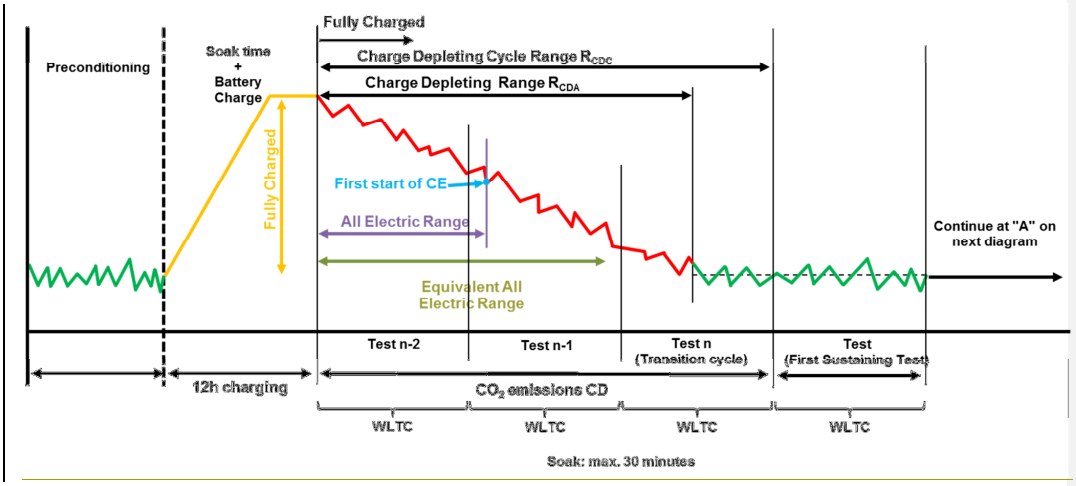
Comment [SMD115]: GTR CORECTION: 03.05.2015: There should be no Appendix 1a but rather just Appendix 1.

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)

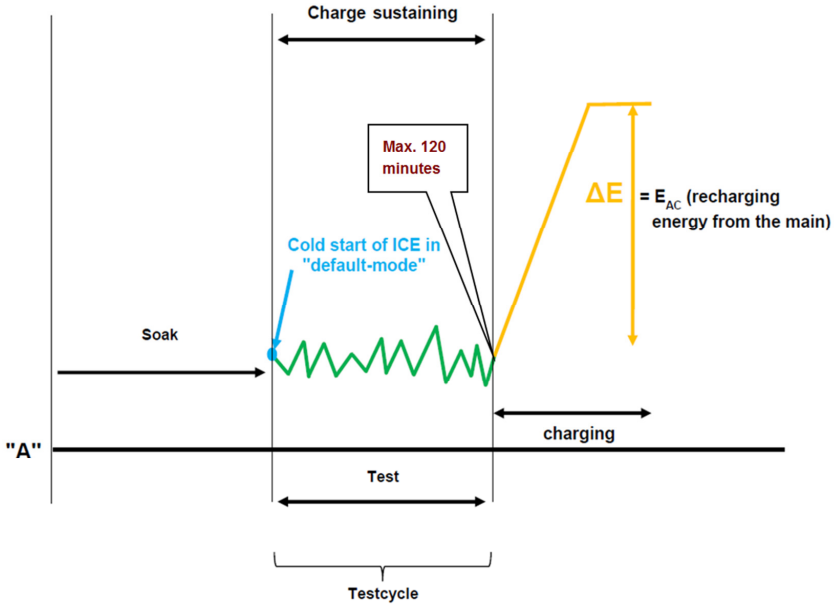
Figure A8.App1a/1
OVC-HEV, Charge-depleting Test





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

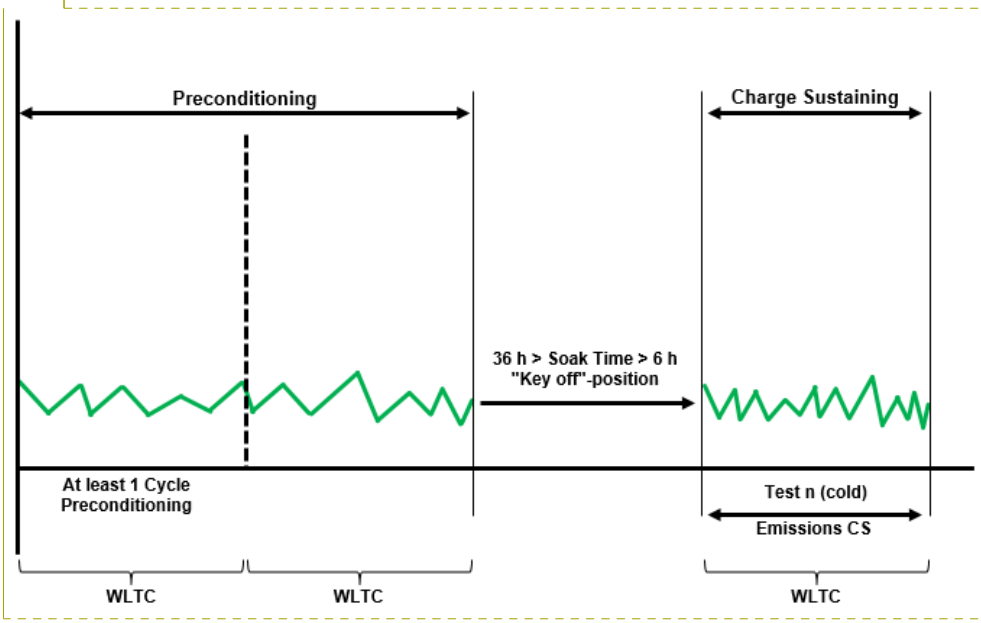


Annex 8 -Appendix 1b

RCB profile, OVC-HEV and NOVC-HEV charge-sustaining test

1. RCB profile OVC-HEV, charge-sustaining test (Figure A8.App1b/1)

Figure A8.App1b/1
OVC-HEV, Charge-sustaining Test



Comment [SMD116]: GTR CORRECTION: March 2015 drafting meeting.
DC: correct soaking time to be greater than 6 but less than 36 hours. Also, CO2 emissions to be deleted.

Comment [SMD117]: GTR CORRECTION: 28.03.2015. Figure deleted and replaced by figure below.

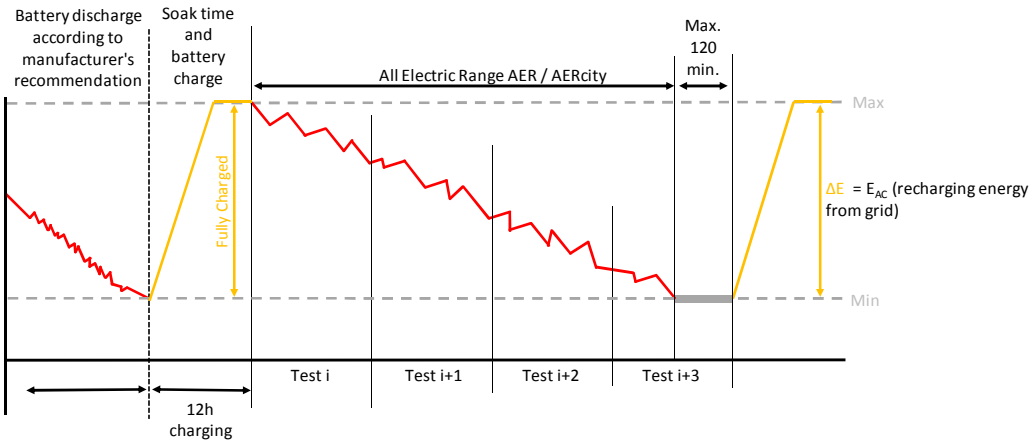
Comment [SMD118]: GTR CORRECTION: 28.03.2015. Replaces the above figure (soak time

Annex 8 -Appendix 1c

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)

Figure A8.App1c/1
PEV, Electric Range and Electric Energy Consumption Test



Annex 8 -Appendix 2

REESS charge balance (RCB) correction

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 :

2.1. The K_{fuel}coefficient 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 responsible authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

2.1.1. K_{fuel} coefficients for the individual phases as well as for the complete test cycle are defined as:

$$K_{fuel} = \frac{(n \times \sum E_{REESSi} \times FC_i - \sum E_{REESSi} \times \sum FC_i)}{n \times \sum E_{REESSi}^2 - (\sum E_{REESSi})^2} \quad (1)$$

Comment [SMD119]: EXPERT PROPOSAL: March 2015 drafting meeting.

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;

E_{REESSi} are the electricity balances measured during the i^{th} test, Wh/km;

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 shall to be evaluated by the responsible authority.

2.2. The fuel consumption correction coefficient shall be determined for the fuel consumption values measured over the 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.

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 K_{CO_2}coefficient 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 responsible authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

3.1.1. The K_{CO_2} coefficient 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} is the CO_2 emissions correction coefficient, g/km/Wh/km;

M_i are the CO_2 emissions measured during the i^{th} test, g/km;

E_{REESSi} is the electricity balance during the i^{th} 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 responsible authority.

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.

3.1.4. CO_2 emissions at zero REESS energy balance shall also be 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:

$$M_0 = M - K_{CO_2} \times \Delta E_{REESSi} \quad (4)$$

where:

M_0 are the CO_2 emissions at zero REESS energy balance, g/km;

K_{CO_2} is the CO_2 emissions correction coefficient, g/km/Wh/km;

ΔE_{REESSi} is the electricity balance measured during test, Wh/km.

Comment [SMD120]: OPEN POINT: 31.03.2015. Definition of M.

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 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 Annex 6.

2.1.1. Alternatively to 2.1 above, the RCB determination method described in paragraph 2.2. of Appendix 2 to 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 responsible 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 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 the following shall be provided to the responsible authority:

(a) When the minimum state of charge of the REESS has been reached during the test procedure defined in paragraph 3. of this Annex;

(b) The correction factors K_{fuel} and K_{CO_2} (as defined in Appendix 2 to this Annex);

(c) The last calibration dates of the instruments (where applicable)..

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 recorded.

Annex 8 -Appendix 4

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, CD and CS 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 CS condition is followed by testing in CD condition, the CS condition test and the CD 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 CD test or the CS test starts.

2.1. OVC-HEV combustion engine and REESS preconditioning when the test procedure starts with a CS 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 CS 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 CS test as described in paragraph 3.2.5. of this 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 ~~criteria~~ is fulfilled according to paragraph 3.2.4.5. of this Annex.

2.1.4. Alternatively, at the request of the manufacturer, the state of charge of the REESS before preconditioning ~~for the charge sustaining test~~ can be set according to the manufacturer's recommendation in order to fulfill the break-off criterion~~achieve a charge balance neutral charge-sustaining test~~.

In such a case, an additional ICE preconditioning procedure, such as that ~~as~~ applicable to conventional vehicles as described in paragraph 1.2.6. of Annex 6, ~~-~~may be applied.

2.1.5. Soaking of the vehicle shall be performed according to paragraph 1.2.7. of 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~~CD 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~~CS condition.

Comment [SMD121]: EXPERT PROPOSAL: 03.11.2014. Proposal from Japan.

Comment [SMD122]: PROPOSAL: 03.11.2014: Japan asks if this should be "may" or "shall".

Comment [SMD123]: OPEN POINT: 02.04.2015. Has this been resolved?

Comment [SMD124]: EXPERT PROPOSAL: 03.11.2014: proposal from Japan.

Comment [SMD125]: EXPERT PROPOSAL: 03.11.2014: proposal from Japan.

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~~CS test as described in paragraph 3.2.5. of this Annex.

2.2.3. Soaking of the vehicle shall be performed according to paragraph 1.2.7. of Annex 6. Forced cooling down shall not be applied to vehicles preconditioned for the test.

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 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.

2.2.5.2. End of charge criterion

The end of charge criterion is reached when a fully charged REESS is detected by the on-board or external instruments.

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

The ~~D~~discharge test procedure shall be performed according to the manufacturer's recommendation. The manufacturer shall 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 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 a special charge procedure has not occurred during the test.

3.1.3. End of charge criterion

The end of charge criterion is reached when a fully charged REESS is detected by the on-board or external instruments.

Annex 8 -Appendix 5

Comment [SMD126]: CONFIRMATION: April 2015 drafting meeting, Stockholm. UF appendix complete.

Utility factor (UF) for OVC-HEVs

1. Utility Factors are ratios based on driving statistics and the ranges achieved in CD mode and CS modes for OVC-HEVs and are used for weighting emissions, CO_2 emissions and fuel consumptions.

2. Each Contracting Party may develop its own UFs.

3. Utility factors shall be calculated according to the following equation:

Comment [SMD127]: EXPERT PROPOSAL: 03.11.2014: Paragraph 3: Proposal from Japan.

$$UF = 1 - e^{\left\{-1\times\left[C_1\times\left(\frac{x}{norm_dist}\right)+C_2\times\left(\frac{x}{norm_dist}\right)^2+C_3\times\left(\frac{x}{norm_dist}\right)^3+\cdots..+C_{10}\times\left(\frac{x}{norm_dist}\right)^{10}\right]\right\}}$$

where:

c_v are utility factor equation constants from Table A8.App.5;

x is the R_{CDC} travelled, km or miles;

norm_dist normalised distance where the utility factor converges to 1.0, km or miles.

	EC	JAPAN	US (fleet)	US (individual)
Norm_dist	800 km	400 km	399.9 miles	400 miles
C1	26.25	11.9	10.52	13.1
C2	-38.94	-32.5	-7.282	-18.7
C3	-631.05	89.5	-26.37	5.22
C4	5964.83	-134	79.08	8.15
C5	-25095	98.9	-77.36	3.53
C6	60380.2	-29.1	26.07	-1.34
C7	-87517	NA	NA	-4.01
C8	75513.8	NA	NA	-3.9
C9	-35749	NA	NA	-1.15
C10	7154.94	NA	NA	3.88

[RESERVED:

Annex 8 - Appendix 6

Determining the range of PEVs on a per-phase basis]

[RESERVED:

Annex 9

Determination of system equivalence]

Page 12: [1] Comment [SMD26]	Serge M. Dubuc	1/21/2015 1:12:00 PM

CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Page 12: [2] Comment [SMD28]	Serge M. Dubuc	1/21/2015 1:14:00 PM

CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Page 12: [3] Comment [SMD30]	Serge M. Dubuc	1/21/2015 1:16:00 PM

CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Page 12: [4] Comment [SMD32]	Serge M. Dubuc	1/21/2015 1:16:00 PM

CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Page 12: [5] Comment [SMD34]	Serge M. Dubuc	1/21/2015 1:19:00 PM

CONFIRMATION: 20.01.2015: From document WLTP-08-45, adopted at WLTP IWG #9, Geneva, January 2015.

Page 12: [6] Comment [SMD36]	Serge M. Dubuc	11/3/2014 2:06:00 PM

GTR CORRECTION: 03.11.2014: DC proposes to move the definition of UFs from Annex 8, Appendix 5 to here.

Page 12: [7] Comment [SMD37]	Serge M. Dubuc	12/18/2014 7:59:00 AM

CONFIRMATION: 17.12.2014: audio/web. this paragraph to remain in Annex 8.

Page 189: [8] Comment [SMD88]	Serge M. Dubuc	11/19/2014 5:29:00 PM

19.11.2014: see wltp-08-33 for proposed text. Proposal:

At the request of the manufacturer and with approval of the authority an "engineering control unit“ which has no effect on original engine calibrations can be used during ki determination.