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| Submitted by the IWG on WLTP | Informal document GRPE-71-25  71st GRPE, 8-12 June 2015,  agenda item 3(b) |

**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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**Economic Commission for Europe**

Inland Transport Committee

**World Forum for Harmonization of Vehicle Regulations**

**162nd session**

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Item 14.1 of the provisional agenda

**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[[1]](#footnote-2)\***

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.

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.

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, CO2, 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 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 as compounds but may be regulated in the near future, such as NO2, 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).

(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 CO2 (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 CO2 saving vehicle technologies that are also the most effective in real driving. The effectiveness of technology costs relative to the real driving CO2 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, CO2 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 (CH4) contribution.

3.1.9. "*Precision*" means the degree to which repeated measurements under unchanged conditions show the same [results](http://en.wikipedia.org/wiki/Result) (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**



value

precision

accuracy

reference value

probability

density

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.

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

(a) Atmospheric pressure: p0 = 100 kPa, unless otherwise specified by regulations;

(b) Atmospheric temperature: T0 = 293 K, unless otherwise specified by regulations;

(c) Dry air density: ρ0 = 1.189  kg/m3, 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*" (RCDA) 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*" (RCDC) 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.

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 (RCDA) 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.

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;

3.6.2. "*Particulate mass*" (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*" () 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*" () 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 High2 | WLTC extra high speed phase for Class 2 vehicles |
| Extra High3 | WLTC extra high speed phase for Class 3 vehicles |
| FID | Flame ionization detector |
| FTIR | Fourier transform infrared analyser |
| GC | Gas chromatograph |
| HEPA | High efficiency particulate air (filter) |
| HFID | Heated flame ionization detector |
| High2 | WLTC high speed phase for Class 2 vehicles |
| High3-1 | WLTC high speed phase for Class 3 vehicles with  km/h |
| High3-2 | WLTC high speed phase for Class 3 vehicles with  km/h |
| LoD | Limit of detection |
| LoQ | Limit of quantification |
| Low1 | WLTC low speed phase for Class 1 vehicles |
| Low2 | WLTC low speed phase for Class 2 vehicles |
| Low3 | WLTC low speed phase for Class 3 vehicles |
| Medium1 | WLTC medium speed phase for Class 1 vehicles |
| Medium2 | WLTC medium speed phase for Class 2 vehicles |
| Medium3-1 | WLTC medium speed phase for Class 3 vehicles with  km/h |
| Medium3-2 | WLTC medium speed phase for Class 3 vehicles with  km/h |
| LPG | Liquefied petroleum gas |
| NDIR | Non-dispersive infrared (analyser) |
| NG/biomethane | Natural gas/biomethane |
| NMC | Non-methane cutter |
| NOVC  NOVC-HEV | Not off-vehicle charging  Not off-vehicle chargeable hybrid electric vehicle |
| OVC  PAO | Off-vehicle charging  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 |
| PND1 | First particle number dilution device |
| PND2 | Second particle number dilution device |
| PTS | Particle transfer system |
| PTT | Particle transfer tube |
| QCL-IR | Infrared quantum cascade laser |
|  | 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

|  |  |
| --- | --- |
| C1 | Carbon 1 equivalent hydrocarbon |
| CH4 | Methane |
| C2H6 | Ethane |
| C2H5OH | Ethanol |
| C3H8 | Propane |
| CO | Carbon monoxide |
| CO2 | Carbon dioxide |
| DOP | Di-octylphthalate |
| THC | Total hydrocarbons (all compounds measurable by an FID) |
| H2O | Water |
| NMHC | Non-methane hydrocarbons |
| NOx | Oxides of nitrogen |
| NO | Nitric oxide |
| NO2 | Nitrogen dioxide |
| N2O | 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 CO2 under WLTP conditions;

(b) Operation strategy of all CO2-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 considered to be part of the family unless approved by the responsible authority.

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, .

1.2. 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  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 (Low1), a medium phase (Medium1) and an additional low phase (Low1).

3.1.2. The Low1 phase is described in Figure A1/1 and Table A1/1.

3.1.3. The Medium1 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 (Low2), a medium phase (Medium2), a high phase (High2) and an extra high phase (Extra High2).

3.2.2. The Low2 phase is described in Figure A1/3 and Table A1/3.

3.2.3. The Medium2 phase is described in Figure A1/4 and Table A1/4.

3.2.4. The High2 phase is described in Figure A1/5 and Table A1/5.

3.2.5. The Extra High2 phase is described in Figure A1/6 and Table A1/6.

3.2.6. At the option of the Contracting Party, the Extra High2 phase may be excluded.

3.3. Class 3 vehicles

Class 3 vehicles are divided into 2 subclasses according to their maximum speed, .

3.3.1. Class 3a vehicles with  km/h

3.3.1.1. A complete cycle shall consist of a low phase (Low3), a medium phase (Medium3-1), a high phase (High3-1) and an extra high phase (Extra High3).

3.3.1.2. The Low3 phase is described in Figure A1/7 and Table A1/7.

3.3.1.3. The Medium3-1 phase is described in Figure A1/8 and Table A1/8.

3.3.1.4. The High3-1 phase is described in Figure A1/10 and Table A1/10.

3.3.1.5. The Extra High3 phase is described in Figure A1/12 and Table A1/12.

3.3.1.6. At the option of the Contracting Party, the Extra High3 phase may be excluded.

3.3.2. Class 3b vehicles with km/h

3.3.2.1. A complete cycle shall consist of a low phase (Low3) phase, a medium phase (Medium3-2), a high phase (High3-2) and an extra high phase (Extra High3).

3.3.2.2. The Low3 phase is described in Figure A1/7 and Table A1/7.

3.3.2.3. The Medium3-2 phase is described in Figure A1/9 and Table A1/9.

3.3.2.4. The High3-2 phase is described in Figure A1/11 and Table A1/11.

3.3.2.5. The Extra High3 phase is described in Figure A1/12 and Table A1/12.

3.3.2.6. At the option of the Contracting Party, the Extra High3 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 Low1**



# Figure A1/2

# **WLTC, Class 1 Vehicles, Phase Medium1**



# Table A1/1

# **WLTC, Class 1 Vehicles, Phase Low1**

| 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 |
| 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 |
| 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 |
| 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 |  |  |  |  |  |  |
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# Table A1/2

# **WLTC, Class 1 Vehicles, Phase Medium1**

| 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 |
| 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 |  |  |  |  |  |  |
| 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 Low2**



# Figure A1/4

# **WLTC, Class 2 Vehicles, Phase Medium2**



# Figure A1/5

# **WLTC, Class 2 Vehicles, Phase High2**



# Figure A1/6

# **WLTC, Class 2 Vehicles, Phase Extra High2**



# Table A1/3

# **WLTC, Class 2 Vehicles, Phase Low2**

| Time in s | Speed in km/h | Time in s | Speed in km/h | Time in s | Speed in km/h | Time in s | Speed in km/h |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0.0 | 47 | 11.6 | 94 | 0.0 | 141 | 36.8 |
| 1 | 0.0 | 48 | 12.4 | 95 | 0.0 | 142 | 35.1 |
| 2 | 0.0 | 49 | 13.2 | 96 | 0.0 | 143 | 32.2 |
| 3 | 0.0 | 50 | 14.2 | 97 | 0.0 | 144 | 31.1 |
| 4 | 0.0 | 51 | 14.8 | 98 | 0.0 | 145 | 30.8 |
| 5 | 0.0 | 52 | 14.7 | 99 | 0.0 | 146 | 29.7 |
| 6 | 0.0 | 53 | 14.4 | 100 | 0.0 | 147 | 29.4 |
| 7 | 0.0 | 54 | 14.1 | 101 | 0.0 | 148 | 29.0 |
| 8 | 0.0 | 55 | 13.6 | 102 | 0.0 | 149 | 28.5 |
| 9 | 0.0 | 56 | 13.0 | 103 | 0.0 | 150 | 26.0 |
| 10 | 0.0 | 57 | 12.4 | 104 | 0.0 | 151 | 23.4 |
| 11 | 0.0 | 58 | 11.8 | 105 | 0.0 | 152 | 20.7 |
| 12 | 0.0 | 59 | 11.2 | 106 | 0.0 | 153 | 17.4 |
| 13 | 1.2 | 60 | 10.6 | 107 | 0.8 | 154 | 15.2 |
| 14 | 2.6 | 61 | 9.9 | 108 | 1.4 | 155 | 13.5 |
| 15 | 4.9 | 62 | 9.0 | 109 | 2.3 | 156 | 13.0 |
| 16 | 7.3 | 63 | 8.2 | 110 | 3.5 | 157 | 12.4 |
| 17 | 9.4 | 64 | 7.0 | 111 | 4.7 | 158 | 12.3 |
| 18 | 11.4 | 65 | 4.8 | 112 | 5.9 | 159 | 12.2 |
| 19 | 12.7 | 66 | 2.3 | 113 | 7.4 | 160 | 12.3 |
| 20 | 13.3 | 67 | 0.0 | 114 | 9.2 | 161 | 12.4 |
| 21 | 13.4 | 68 | 0.0 | 115 | 11.7 | 162 | 12.5 |
| 22 | 13.3 | 69 | 0.0 | 116 | 13.5 | 163 | 12.7 |
| 23 | 13.1 | 70 | 0.0 | 117 | 15.0 | 164 | 12.8 |
| 24 | 12.5 | 71 | 0.0 | 118 | 16.2 | 165 | 13.2 |
| 25 | 11.1 | 72 | 0.0 | 119 | 16.8 | 166 | 14.3 |
| 26 | 8.9 | 73 | 0.0 | 120 | 17.5 | 167 | 16.5 |
| 27 | 6.2 | 74 | 0.0 | 121 | 18.8 | 168 | 19.4 |
| 28 | 3.8 | 75 | 0.0 | 122 | 20.3 | 169 | 21.7 |
| 29 | 1.8 | 76 | 0.0 | 123 | 22.0 | 170 | 23.1 |
| 30 | 0.0 | 77 | 0.0 | 124 | 23.6 | 171 | 23.5 |
| 31 | 0.0 | 78 | 0.0 | 125 | 24.8 | 172 | 24.2 |
| 32 | 0.0 | 79 | 0.0 | 126 | 25.6 | 173 | 24.8 |
| 33 | 0.0 | 80 | 0.0 | 127 | 26.3 | 174 | 25.4 |
| 34 | 1.5 | 81 | 0.0 | 128 | 27.2 | 175 | 25.8 |
| 35 | 2.8 | 82 | 0.0 | 129 | 28.3 | 176 | 26.5 |
| 36 | 3.6 | 83 | 0.0 | 130 | 29.6 | 177 | 27.2 |
| 37 | 4.5 | 84 | 0.0 | 131 | 30.9 | 178 | 28.3 |
| 38 | 5.3 | 85 | 0.0 | 132 | 32.2 | 179 | 29.9 |
| 39 | 6.0 | 86 | 0.0 | 133 | 33.4 | 180 | 32.4 |
| 40 | 6.6 | 87 | 0.0 | 134 | 35.1 | 181 | 35.1 |
| 41 | 7.3 | 88 | 0.0 | 135 | 37.2 | 182 | 37.5 |
| 42 | 7.9 | 89 | 0.0 | 136 | 38.7 | 183 | 39.2 |
| 43 | 8.6 | 90 | 0.0 | 137 | 39.0 | 184 | 40.5 |
| 44 | 9.3 | 91 | 0.0 | 138 | 40.1 | 185 | 41.4 |
| 45 | 10 | 92 | 0.0 | 139 | 40.4 | 186 | 42.0 |
| 46 | 10.8 | 93 | 0.0 | 140 | 39.7 | 187 | 42.5 |
| 188 | 43.2 | 237 | 33.5 | 286 | 32.5 | 335 | 25.0 |
| 189 | 44.4 | 238 | 35.8 | 287 | 30.9 | 336 | 24.6 |
| 190 | 45.9 | 239 | 37.6 | 288 | 28.6 | 337 | 23.9 |
| 191 | 47.6 | 240 | 38.8 | 289 | 25.9 | 338 | 23.0 |
| 192 | 49.0 | 241 | 39.6 | 290 | 23.1 | 339 | 21.8 |
| 193 | 50.0 | 242 | 40.1 | 291 | 20.1 | 340 | 20.7 |
| 194 | 50.2 | 243 | 40.9 | 292 | 17.3 | 341 | 19.6 |
| 195 | 50.1 | 244 | 41.8 | 293 | 15.1 | 342 | 18.7 |
| 196 | 49.8 | 245 | 43.3 | 294 | 13.7 | 343 | 18.1 |
| 197 | 49.4 | 246 | 44.7 | 295 | 13.4 | 344 | 17.5 |
| 198 | 48.9 | 247 | 46.4 | 296 | 13.9 | 345 | 16.7 |
| 199 | 48.5 | 248 | 47.9 | 297 | 15.0 | 346 | 15.4 |
| 200 | 48.3 | 249 | 49.6 | 298 | 16.3 | 347 | 13.6 |
| 201 | 48.2 | 250 | 49.6 | 299 | 17.4 | 348 | 11.2 |
| 202 | 47.9 | 251 | 48.8 | 300 | 18.2 | 349 | 8.6 |
| 203 | 47.1 | 252 | 48.0 | 301 | 18.6 | 350 | 6.0 |
| 204 | 45.5 | 253 | 47.5 | 302 | 19.0 | 351 | 3.1 |
| 205 | 43.2 | 254 | 47.1 | 303 | 19.4 | 352 | 1.2 |
| 206 | 40.6 | 255 | 46.9 | 304 | 19.8 | 353 | 0.0 |
| 207 | 38.5 | 256 | 45.8 | 305 | 20.1 | 354 | 0.0 |
| 208 | 36.9 | 257 | 45.8 | 306 | 20.5 | 355 | 0.0 |
| 209 | 35.9 | 258 | 45.8 | 307 | 20.2 | 356 | 0.0 |
| 210 | 35.3 | 259 | 45.9 | 308 | 18.6 | 357 | 0.0 |
| 211 | 34.8 | 260 | 46.2 | 309 | 16.5 | 358 | 0.0 |
| 212 | 34.5 | 261 | 46.4 | 310 | 14.4 | 359 | 0.0 |
| 213 | 34.2 | 262 | 46.6 | 311 | 13.4 | 360 | 1.4 |
| 214 | 34.0 | 263 | 46.8 | 312 | 12.9 | 361 | 3.2 |
| 215 | 33.8 | 264 | 47.0 | 313 | 12.7 | 362 | 5.6 |
| 216 | 33.6 | 265 | 47.3 | 314 | 12.4 | 363 | 8.1 |
| 217 | 33.5 | 266 | 47.5 | 315 | 12.4 | 364 | 10.3 |
| 218 | 33.5 | 267 | 47.9 | 316 | 12.8 | 365 | 12.1 |
| 219 | 33.4 | 268 | 48.3 | 317 | 14.1 | 366 | 12.6 |
| 220 | 33.3 | 269 | 48.3 | 318 | 16.2 | 367 | 13.6 |
| 221 | 33.3 | 270 | 48.2 | 319 | 18.8 | 368 | 14.5 |
| 222 | 33.2 | 271 | 48.0 | 320 | 21.9 | 369 | 15.6 |
| 223 | 33.1 | 272 | 47.7 | 321 | 25.0 | 370 | 16.8 |
| 224 | 33.0 | 273 | 47.2 | 322 | 28.4 | 371 | 18.2 |
| 225 | 32.9 | 274 | 46.5 | 323 | 31.3 | 372 | 19.6 |
| 226 | 32.8 | 275 | 45.2 | 324 | 34.0 | 373 | 20.9 |
| 227 | 32.7 | 276 | 43.7 | 325 | 34.6 | 374 | 22.3 |
| 228 | 32.5 | 277 | 42.0 | 326 | 33.9 | 375 | 23.8 |
| 229 | 32.3 | 278 | 40.4 | 327 | 31.9 | 376 | 25.4 |
| 230 | 31.8 | 279 | 39.0 | 328 | 30.0 | 377 | 27.0 |
| 231 | 31.4 | 280 | 37.7 | 329 | 29.0 | 378 | 28.6 |
| 232 | 30.9 | 281 | 36.4 | 330 | 27.9 | 379 | 30.2 |
| 233 | 30.6 | 282 | 35.2 | 331 | 27.1 | 380 | 31.2 |
| 234 | 30.6 | 283 | 34.3 | 332 | 26.4 | 381 | 31.2 |
| 235 | 30.7 | 284 | 33.8 | 333 | 25.9 | 382 | 30.7 |
| 236 | 32.0 | 285 | 33.3 | 334 | 25.5 | 383 | 29.5 |
| 384 | 28.6 | 433 | 0.0 | 482 | 2.5 | 531 | 26.0 |
| 385 | 27.7 | 434 | 0.0 | 483 | 5.2 | 532 | 26.5 |
| 386 | 26.9 | 435 | 0.0 | 484 | 7.9 | 533 | 26.9 |
| 387 | 26.1 | 436 | 0.0 | 485 | 10.3 | 534 | 27.3 |
| 388 | 25.4 | 437 | 0.0 | 486 | 12.7 | 535 | 27.9 |
| 389 | 24.6 | 438 | 0.0 | 487 | 15.0 | 536 | 30.3 |
| 390 | 23.6 | 439 | 0.0 | 488 | 17.4 | 537 | 33.2 |
| 391 | 22.6 | 440 | 0.0 | 489 | 19.7 | 538 | 35.4 |
| 392 | 21.7 | 441 | 0.0 | 490 | 21.9 | 539 | 38.0 |
| 393 | 20.7 | 442 | 0.0 | 491 | 24.1 | 540 | 40.1 |
| 394 | 19.8 | 443 | 0.0 | 492 | 26.2 | 541 | 42.7 |
| 395 | 18.8 | 444 | 0.0 | 493 | 28.1 | 542 | 44.5 |
| 396 | 17.7 | 445 | 0.0 | 494 | 29.7 | 543 | 46.3 |
| 397 | 16.6 | 446 | 0.0 | 495 | 31.3 | 544 | 47.6 |
| 398 | 15.6 | 447 | 0.0 | 496 | 33.0 | 545 | 48.8 |
| 399 | 14.8 | 448 | 0.0 | 497 | 34.7 | 546 | 49.7 |
| 400 | 14.3 | 449 | 0.0 | 498 | 36.3 | 547 | 50.6 |
| 401 | 13.8 | 450 | 0.0 | 499 | 38.1 | 548 | 51.4 |
| 402 | 13.4 | 451 | 0.0 | 500 | 39.4 | 549 | 51.4 |
| 403 | 13.1 | 452 | 0.0 | 501 | 40.4 | 550 | 50.2 |
| 404 | 12.8 | 453 | 0.0 | 502 | 41.2 | 551 | 47.1 |
| 405 | 12.3 | 454 | 0.0 | 503 | 42.1 | 552 | 44.5 |
| 406 | 11.6 | 455 | 0.0 | 504 | 43.2 | 553 | 41.5 |
| 407 | 10.5 | 456 | 0.0 | 505 | 44.3 | 554 | 38.5 |
| 408 | 9.0 | 457 | 0.0 | 506 | 45.7 | 555 | 35.5 |
| 409 | 7.2 | 458 | 0.0 | 507 | 45.4 | 556 | 32.5 |
| 410 | 5.2 | 459 | 0.0 | 508 | 44.5 | 557 | 29.5 |
| 411 | 2.9 | 460 | 0.0 | 509 | 42.5 | 558 | 26.5 |
| 412 | 1.2 | 461 | 0.0 | 510 | 39.5 | 559 | 23.5 |
| 413 | 0.0 | 462 | 0.0 | 511 | 36.5 | 560 | 20.4 |
| 414 | 0.0 | 463 | 0.0 | 512 | 33.5 | 561 | 17.5 |
| 415 | 0.0 | 464 | 0.0 | 513 | 30.4 | 562 | 14.5 |
| 416 | 0.0 | 465 | 0.0 | 514 | 27.0 | 563 | 11.5 |
| 417 | 0.0 | 466 | 0.0 | 515 | 23.6 | 564 | 8.5 |
| 418 | 0.0 | 467 | 0.0 | 516 | 21.0 | 565 | 5.6 |
| 419 | 0.0 | 468 | 0.0 | 517 | 19.5 | 566 | 2.6 |
| 420 | 0.0 | 469 | 0.0 | 518 | 17.6 | 567 | 0.0 |
| 421 | 0.0 | 470 | 0.0 | 519 | 16.1 | 568 | 0.0 |
| 422 | 0.0 | 471 | 0.0 | 520 | 14.5 | 569 | 0.0 |
| 423 | 0.0 | 472 | 0.0 | 521 | 13.5 | 570 | 0.0 |
| 424 | 0.0 | 473 | 0.0 | 522 | 13.7 | 571 | 0.0 |
| 425 | 0.0 | 474 | 0.0 | 523 | 16.0 | 572 | 0.0 |
| 426 | 0.0 | 475 | 0.0 | 524 | 18.1 | 573 | 0.0 |
| 427 | 0.0 | 476 | 0.0 | 525 | 20.8 | 574 | 0.0 |
| 428 | 0.0 | 477 | 0.0 | 526 | 21.5 | 575 | 0.0 |
| 429 | 0.0 | 478 | 0.0 | 527 | 22.5 | 576 | 0.0 |
| 430 | 0.0 | 479 | 0.0 | 528 | 23.4 | 577 | 0.0 |
| 431 | 0.0 | 480 | 0.0 | 529 | 24.5 | 578 | 0.0 |
| 432 | 0.0 | 481 | 1.4 | 530 | 25.6 | 579 | 0.0 |
| 580 | 0.0 |  |  |  |  |  |  |
| 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 |  |  |  |  |  |  |
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# Table A1/4

# **WLTC, Class 2 Vehicles, Phase Medium2**

| 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 |
| 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 |
| 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 High2**

| 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 |
| 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 |
| 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 High2**

| 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 |
| 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 Low3**



# Figure A1/8

# **WLTC, Class 3 Vehicles, Phase Medium3-1**



# Figure A1/9

# **WLTC, Class 3 Vehicles, Phase Medium3-2**



# Figure A1/10

# **WLTC, Class 3 Vehicles, Phase High3-1**



# Figure A1/11

# **WLTC, Class 3 Vehicles, Phase High3-2**



# Figure A1/12

# **WLTC, Class 3 Vehicles, Phase Extra High3**



# Table A1/7

# **WLTC, Class 3 Vehicles, Phase Low3**

| 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 |
| 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 |
| 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 |
| 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 |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
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# Table A1/8

# **WLTC, Class 3 Vehicles, Phase Medium3-1**

| 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 |
| 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 |
| 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 Medium3-2**

| 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 |
| 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 |
| 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 High3-1**

| 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 |
| 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 |
| 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 High3-2**

| 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 |
| 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 |
| 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 High3**

| 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 |
| 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, .

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:

(1)

where:

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:

(2)

with .

For , . (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:

(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:

(5)

With .

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:

(6)

where:

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:

(7)

with .

For , . (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:

(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:

(10)

with .

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:

(11)

where:

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:

(12)

with .

For , . (13)

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

(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:

(15)

with .

7.3. Determination of the downscaling factor

The downscaling factor, , is a function of the ratio, , between the maximum required power of the cycle phases where the downscaling is to be applied and the rated power of the vehicle, .

The maximum required power, in kW, is related to a specific time i and the corresponding vehicle speed, vi, in the cycle trace and is calculated as follows:

(16)

where:

is the constant road load coefficient, N;

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

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

is the test mass,  kg;

vi 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, and acceleration values, , are as follows:

 km/h,  m/s² for Class 1,

 km/h,  m/s² for Class 2,

 km/h,  m/s² for Class 3.

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

is calculated using the following equation:

(17)

The downscaling factor, , is calculated using the following equations:

if , then (18)

if , then (19)

The calculation parameter/coefficients, , and , are as follows:

Class 1 , ,

Class 2 , , .

Class 3 , .

The resulting 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) , the maximum rated engine power as declared by the manufacturer, kW;

(b) , 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) , idling speed, min-1;

(d) , the number of forward gears;

(e) nmin\_drive, minimum engine speed when the vehicle is in motion, min-1

for ngear = 1, nmin\_drive = nidle, (1)

for ngear = 2,

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

nmin\_drive = 1.15 ×nidle

for all other driving conditions:

.

nmin\_drive = 0.9 x nidle, (2)

for ngear > 2, nmin\_drive is determined by :

nmin\_drive = nidle + 0.125 ×(s-nidle ) (3)

Higher values may be used if requested by the manufacturer.

(f) , the ratio obtained by dividing n by v for each gear , to , min-1/km/h;

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

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

(i) ngvmax, the gear in which the maximum vehicle speed is reached, and is determined as follows:

If vmax(ngmax) ≥ vmax(ngmax-1), then,

ngvmax = ngmax (4)

otherwise, ngvmax = ngmax -1 (5)

where:

vmax(ngmax) is the vehicle speed at which the required road load power equals the available power Pwot in gear ngmax;

vmax(ngmax-1) is the vehicle speed at which the required road load power equals the available power Pwot in the next lower gear.

The required road load power, kW, at second j, shall be calculated as follows: (6)

where:

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

(j) nmax\_95 is the minimum engine speed where 95 per cent of rated power is reached, min-1;

(k) nmax(ngvmax) = ndv(ngvmax) × vmax,cycle (7)

where:

vmax,cycle is the maximum speed of the vehicle speed trace according to Annex 1, km/h;

(l) nmax is the maximum of nmax\_95 and nmax(ngvmax), min-1;

(m) pwot(n) is the full load power curve over the engine speed range from idling speed to nmax;

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 nidle and the last one at nmax 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 of the cycle trace, the power required to overcome driving resistance and to accelerate shall be calculated using the following equation:

(8)

where:

is the constant road load coefficient, N;

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

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

is the required power at second j, kW;

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

is the vehicle acceleration at second j, m/s², ; (9)

is the vehicle test mass, kg;

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  km/h, it shall be assumed that the vehicle is standing still and the engine speed shall be set to .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  km/h of the cycle trace and each gear i, to , the engine speed, ,shall be calculated using the following equation:

(10)

3.3. Selection of possible gears with respect to engine speed

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

(a) all gears i < ngvmax where nmin\_drive ≤ ni,j ≤ nmax\_95, and

(b) all gears i ≥ ngvmax where nmin\_drive ≤ ni,j ≤ nmax(ngvmax)

If aj ≤ 0 and ni,j drops below nidle, ni,j shall be set to nidle and the clutch shall be disengaged.

If aj > 0 and ni,j drops below (1.15 × nidle), ni,j shall be set to (1.15 × nidle) 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, shall be calculated using the following equation:

(11)

where:

is the rated power, kW;

is the power available at ni,j at full load condition from the full load power curve;

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 nidle and nstart, and exponentially approaching 0 at nend as described by the following requirements:

If n ≤ nstart, then ASM = ASM0, (12)

If n > nstart, then:

ASM = ASM0 x exp(ln(0.005/ASM0) × (nstart – n)/(nstart – nend)) (13)

ASM0, nstart and nend shall be defined by the manufacturer but shall fulfil the following conditions:

nstart ≥ nidle,

nend > nstart.

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)

The initial gear to be used for each second of the cycle trace is the highest final possible gear, . 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 ngear > 2 shall be used as long as the engine speed does not drop below nmin\_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 × nidle. If the engine speed drops below nidle, 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 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 , , shall be replaced by , , ;

(ii) gear sequence , , , shall be replaced by , , , ;

(iii) gear sequence , , ,, shall be replaced by , ,, , ;

(iv) gear sequence , ,, , , shall be replaced by , , , , , ;

(v) gear sequence , ,,, , , shall be replaced by , , , , , , .

In all cases (i) to (v), 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/m3 | 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/m3 | 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/m3 | 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 |
| N2 | % mole |  |  |  | ISO 6974 |
| Sulphur content | mg/m3(2) | — | — | 10 | ISO 6326-5 |
| Wobbe Index (net) | MJ/m3(3) | 48.2 | 47.2 | 49.2 |  |
| (1) Inerts (different from N2) + 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 |
| C3 + hydrocarbon | % v/v | - | 5.0 | KS M ISO 6974, ASTM D1946, ASTM D1945-81,  JIS K 0114 |
| C6 + 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(CO2, N2 ,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 |
| N2 | % mole | 14 | 12 | 16 | ISO 6974 |
| Sulphur content | mg/m3(2) | — | — | 10 | ISO 6326-5 |
| Wobbe Index (net) | MJ/m3(3) | 39.4 | 38.2 | 40.6 |  |
| (1) Inerts (different from N2) + 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 C3+C4 | % mole |  | 8 |
| HC of C5 or more | % mole |  | 0.1 |
| Other gases (H2+O2+N2+CO+CO2) | % mole |  | 1.0 |
| Sulphur content | mg/Nm3 |  | 10 |
| Wobbe Index | WI | 13.260 | 13.730 |
| Gross Calorific value | kcal/Nm3 | 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 | mm2/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/m3 | 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 | mm2/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 ℃ | mm2/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/cm³ | 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/m3 | 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 | mm2/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, vmax, 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, , and frontal area, , within the road load vehicle family shall meet the criteria in this paragraph.

These criteria are only valid for determining values in order to use the CO2 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, , shall not exceed 1 per cent. See Figure A4/1.

Figure A4/1

**Turbulence Intensity**



(1)

where:

is turbulence intensity;

is turbulent velocity fluctuation, m/s;

is free flow velocity, m/s.

3.2.4. Solid blockage ratio

The vehicle blockage ratio, , 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.

(2)

where:

is vehicle blockage ratio, per cent;

is frontal area of the vehicle, m²;

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.

where:

is the standard deviation of the pressure ratio ;

is the variation of total pressure between the measurement points, N/m2;

is the dynamic pressure, N/ m².

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

≤ 1 per cent (3)

where:

is the pressure coefficient.

3.2.9. Boundary layer thickness

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

 mm

where:

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, , shall not exceed 10 per cent.

(4)

where:

is the relative blockage ratio of the restraint system, per cent;

is the frontal area of the restraint system projected on the nozzle face, m²;

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, . 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, and shall be used, i.e. the average mass 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 CO2 interpolation method in paragraph 3.2.3.2 of Annex 7. For individual vehicles in the CO2 interpolation family, the CO2 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:

(5)

where:

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;

is the tyre soaking temperature, Kelvin (K);

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 | Low1+ Medium1 | 58 km/h | NA |
| Class2 | Low2+ Medium2+ High2 + Extra High2 | 111 km/h | NA |
| Low2+ Medium2+ High2 | 77 km/h | Extra High (111 km/h) |
| Class3 | Low3+ Medium3+ High3+ Extra High3 | 118 km/h | NA |
| Low3+ Medium3+ High3 | 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, ,as the elapsed time from vehicle speed () to () 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 pj, in per cent, defined below.

(6)

where:

is the statistical accuracy of the measurements made at reference speed vj;

is the number of pairs of measurements;

is the mean coastdown time at reference speed vj in seconds, given by the equation:

(7)   
where is the harmonized average coastdown time of the ith pair of measurements at velocity vj, seconds (s), given by the equation:

(8)  
where:

and are the coastdown times of the ith measurement at reference speed vj, in seconds (s), in each direction, respectively;

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

σj (9)

is a coefficient given in Table A4/3.

Table A4/3

**Coefficient as Function of**

| n | h | h/ | n | h | h/ |
| --- | --- | --- | --- | --- | --- |
| 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, and , at reference speed in directions a and b, , are determined by the equations:

(10)

and

(11)

where:

is the total resistance at reference speed, j, in direction a, N;

is the total resistance at reference speed, j, in direction b, N;

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

is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdowns on the road, in kilograms (kg); shall be measured or calculated using an appropriate technique agreed by the responsible authority. Alternatively, may be estimated to be 3 per cent of the sum of the mass in running order and 25 kg for the CO2 interpolation family;

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

(12)  
and . (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.

(14)

where:

is the harmonized average of alternate coastdown time measurements at velocity , seconds (s), given by:

(15)  
where and are the coastdown times at velocity , seconds (s),in each direction, respectively;

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

is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdowns on the road, in kilograms (kg); shall be measured or calculated using an appropriate technique. Alternatively, may be estimated to be 3 per cent of the sum of the mass in running order and 25 kg for the CO2 interpolation family.

The coefficients , and 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,, 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 |
| --- | --- | --- |
|  | m2 | frontal area |
| … | degrees-1 | coefficients for aerodynamic drag, as a function of yaw angle |
|  | N | coefficient of mechanical drag |
|  | N/(km/h) | coefficient of mechanical drag |
|  | N/(km/h)2 | coefficient of mechanical drag |
|  |  | coefficient of aerodynamic drag at yaw angle Y |
|  | N | drag |
|  | N | aerodynamic drag |
|  | N | front axle drag (including driveline) |
|  | N | gravitational drag |
|  | N | mechanical drag |
|  | N | rear axle drag (including driveline) |
|  | N | tyre rolling resistance |
|  | m/s2 | acceleration |
|  | m/s2 | gravitational constant |
|  | kg | mass of vehicle |
|  | kg | effective vehicle mass (including rotating components) |
|  | kg/m3 | air density |
|  | s | Time |
|  | K | Temperature |
|  | km/h | vehicle speed |
|  | km/h | apparent wind speed relative to vehicle |
|  | 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:

(16)

where:

; (17)

; (18)

is the effective vehicle mass, kg.

4.3.2.5.2. Mechanical drag modelling

Mechanical drag consisting of separate components representing tyre, , and front and rear axle frictional losses, and , including transmission losses) can be modelled as a three-term polynomial as a function of speed, v, as in the equation below:

(19)

where:

, , and 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, (Y), is modelled as a four-term polynomial as a function of yaw angle, as in the equation below:

(20)

where:

to are constant coefficients whose values are determined in the data analysis;

is the yaw angle, degrees.

The aerodynamic drag coefficient is combined with the vehicle frontal area, Af, , and the relative wind velocity, , to determine the aerodynamic drag, , according to the following two equations:

(21)

(22)

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

(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,   , 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,, relative wind velocity,and yaw, 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 , and 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 , etc., shall be selected where and 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 , , , and 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. , , , , , , and givenand shall be determined.

4.3.2.6.4. Identifying outliers

For each data point, a predicted force, , 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 and , and shall be determined.

4.3.2.6.8. Constrained analysis option

In a constrained analysis, the vehicle frontal area, , and the drag coefficient, , 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, , actual torque, , and time over a period of at least 5 seconds shall be recorded for every at a sampling frequency of at least 10 Hz. The data sets collected over one time period for a reference speed shall be referred to as one measurement.

4.4.2.3. Velocity deviation

The velocity deviation, , from the mean velocity, , (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 , km/h, and mean torque, , Nm, over a time period, shall be calculated from the data sets collected in paragraph4.4.2.2. above as follows:

(24)

and

(25)

where:

is vehicle speed of the ith data set, km/h;

is the number of data sets;

is torque of the ith data set, Nm;

is the compensation term for speed drift, Nm, given by the following equation:

. (26)

shall be no greater than 5 per cent of the mean torque before compensation, and may be neglected if is not greater than ± 0.005 m/s2;

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

is the dynamic radius of the tyre, m, given by the equation:

(27)

where:

is the rotational frequency of the driven tyre, s-1;

is the mean acceleration, m/s2, which shall be calculated by the equation

(28)

where:

is the time at which the ith 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 and in both directions, a and b, have been obtained, for which satisfies the accuracy, ρ, in per cent, according to the equation:

(29) where:

is the number pairs of measurements for ;

is the running resistance at the speed , Nm, given by the equation:

(30)

where:

is the average torque of the ith pair of measurements at speed , Nm and given by:

(31)  
where:

and are the mean torques of the ith measurement at speed determined in paragraph 4.4.3.1. above for each direction, a and b respectively, expressed in Nm;

is the standard deviation, Nm, defined by the equation

; (32)

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, , shall not deviate from its mean, , by more than ± 1 km/h or 2 per cent of the average speed, , whichever is greater. The values of and shall be calculated as follows:

(33)

(34)

where:

and are the mean speeds of the ith pair of measurements at velocity 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 (, ) and (, ) at all reference speeds ,(, , etc.) described in paragraph 4.3.1.1. above to determine the coefficients , , , , and :

(35)

(36)

where:

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

and are constant terms in directions a and b, Nm;

and are the coefficients of the first order term in directions a and b, Nm∙(h/km);

and are the coefficients of the second order term in directions a and b, Nm∙(h/km)2;

is vehicle velocity, km/h.

The average total torque is calculated by the following equation:

(37)

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

(38)

(39)

(40)

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

The coefficients , and 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, K2, shall be determined as follows:

(41)

where:

is the mean atmospheric temperature, Kelvin (K);

is the mean atmospheric pressure, kPa.

4.5.2. Rolling resistance correction factor

The correction factor, , 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:

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, given in paragraph 4.3.1.4.5. above, or from 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, for the coastdown method or for the torque meter method shall be calculated by the equations:

or (42)

where:

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

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

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

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

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, for the test mass of test vehicle H shall be determined as follows:

(43)

where:

is a constant term, N;

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

is the actual test mass of test vehicle H (the average mass ); (see paragraph 4.3.1.4.4. of this Annex), kg.

4.5.4.2. Test vehicle L

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

(44)

where:

is a constant term, N;

is the test mass of test vehicle L, kg;

is the actual test mass of the test vehicle L (the average mass ; 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.:

(45)

where:

is the corrected total resistance, N;

is the constant term, N;

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

is the coefficient of the second order term, N∙(h/km)2;

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

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

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

is the mean atmospheric temperature, °C;

is vehicle velocity, km/h;

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:

(46) where:

is the corrected total running resistance, Nm;

is the constant term, Nm;

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

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

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

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

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

is the vehicle velocity, km/h;

T is the mean atmospheric temperature, °C;

is the mean air density, kg/m³;

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, , shall be calculated for the reference speed points..

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

(47)

where:

is the calculated default road load force as a function of vehicle velocity, N;

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

; (48)

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

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

;(49)

is vehicle velocity, km/h;

test mass, kg;

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

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

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 f0, f1 and f2 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 f0, f1 and f2 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:

1. The difference in cycle energy, expressed as εk, 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:

(XX)

where:

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

Ek,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;

Ek,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.;

1. The average, , of the three differences shall be within [2 ] per cent.

(XX)

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 Cd × Af representative of the on-road Cd × Af value.

For all Cd × Af 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.

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.

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.

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.

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 )×(1+K\_0 (T-293 K)) (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\*ρ\_0/2\*(v\_j^2)/〖3.6〗^2 (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 | Low1+ Medium1 | NA | Low1+ Medium1 |
| Class 2 | Low2 + Medium2 + High2 + Extra High2 | NA | Low2 + Medium2 + High2 + Extra High2 |
| Low2 + Medium2 + High2 | Yes (Extra High2) |
|  | No | Low2+ Medium2+ High2 |
| Class 3 | Low3 + Medium3 + High3 + Extra High3 | Low3 + Medium3 + High3 + Extra High3 | Low3 + Medium3 + High3 + Extra High3 |
| Low3 + Medium3 + High3 | Yes (Extra High3) |
|  | No | Low3 + Medium3 + High3 |

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, f0a, f1a and f2a, for the alternative warm-up procedure shall be equal to or higher than the cycle energy demand calculated with the target road load parameters, f0, f1, and f2, for each applicable phase.

The corrected road load parameters, f0a, f1a and f2a, shall be calculated according to the following equations:

(XX)

(YY)

(ZZ)

where:

Ad\_alt, Bd\_alt and Cd\_alt are the chassis dynamometer setting coefficients after the alternative warm-up procedure;

Ad\_WLTC, Bd\_WLTC and Cd\_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, f0a, f1a and f2a, 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, f0, f1 and f2, 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.

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, , and , of the following equation:

(50)

where:

is the chassis dynamometer setting load, N;

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

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

(a) (51)

for single-axis chassis dynamometers, or

(52) for dual-axis chassis dynamometers, where , and 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, , and for each reference speed, :

(53)

where:

is the target road load at reference speed , N;

is the jth reference speed, km/h.

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

8.1.3.2.1. Fixed run method

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

8.1.3.2.2. Iterative method

The calculated forces in the specified speed ranges shall be within a tolerance of ± 10 N after a least squares regression of the forces for two consecutive coastdowns.

If an error at any reference speed does not satisfy the criterion of the method described in this paragraph, paragraph 8.1.4. below shall be used to adjust the chassis dynamometer load setting.

8.1.4. Adjustment

The chassis dynamometer setting load shall be adjusted in accordance with the procedure specified in paragraph 1 of Appendix 2 to this 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, , and , of the following equation:

(54)

where:

is the chassis dynamometer setting load, N;

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

The following coefficients are recommended for the initial load setting:

(a) (55) for single-axis chassis dynamometers, or

(56)

for dual-axis chassis dynamometers, where , and are the coefficients for the target torque; is the dynamic radius of the tyre on the chassis dynamometer, metres, obtained by averaging the 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, , and for each reference speed, .

(57)

where:

is the target road load at reference speed , N;

is the jth reference speed, km/h;

is the dynamic radius of the tyre on the chassis dynamometer, metres, obtained by averaging the values calculated according to paragraph 2.1. in Appendix 1 to this Annex.

8.2.3.2. The error, , in per cent of the simulated road load, shall be calculated. is determined according to the method specified in Appendix 1 to this Annex, paragraph 2, for target road load, , at each reference speed, .

(58)

obtained in paragraph 2.1. of Appendix 1 to this Annex may be used in the above equation instead of .

Errors at all reference speeds shall satisfy the following error criteria in two consecutive coastdown runs, unless otherwise specified by regulations.

 per cent for  km/h

 per cent for 20 km/h  km/h

 per cent for  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 4.3.1.3. 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, for each reference speed, , 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:

(1)

where

is the measured road load for each reference speed , N;

is the equivalent inertia mass of the chassis dynamometer, kg;

is the equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the road, kg; may be measured or calculated by an appropriate technique. As an alternative, may be estimated as 3 per cent of the sum of the mass in running order and 25 kg ;

is the coastdown time corresponding to speed , seconds (s).

1.2. The coefficients , and of the following approximate equation shall be determined using a least square regression using the calculated values of :

(2)

1.3. The simulated road load for each reference speed shall be determined using the following equation, using the calculated , and :

(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, for each reference speed , shall be conducted as described in paragraphs 2.1. to 2.3. inclusive of this Appendix.

2.1. The mean speed , and the mean torque, , for each reference speed shall be calculated using the following equations:

(4)

and

(5)

where:

is the vehicle speed of the ith data set, km/h;

is the number of data sets;

is the torque of the ith data set, Nm;

is the compensation term for the speed drift,Nm, given by the following equation:

(6)

shall be no greater than 5 per cent of the mean torque before compensation, and may be neglected if || is no greater than 0.005 m/s2;

is the equivalent inertia mass of the chassis dynamometer, kg;

is the equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the dynamometer, kg; may be measured or calculated by an appropriate technique. As an alternative, may be estimated as 3 per cent of the sum of the mass in running order and 25 kg;

is the mean acceleration, m/s2, which shall be calculated using the following equation:

(7)

where:

is the time at which the ith data set was sampled, seconds (s);

is the dynamic radius of the tyre, metres, for the jth reference speed given by the equation:

(8)

where:

is the rotational frequency of the driven tyre, s-1.

2.2. The coefficients , and of the following approximate equation shall be determined by the least square regression using the calculated and the .

(9)

2.3. The simulated road load for each reference speed shall be determined using the following equation and the calculated , and :

(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:

(1)

Therefore:

(2)

(3)

(4)

The parameters used in these equations are the following:

is the initial chassis dynamometer setting load, N;

is the adjusted chassis dynamometer setting load, N;

is the adjustment road load, which is equal to , N;

is the simulated road load at reference speed , N;

is the target road load at reference speed , N;

, and 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:

(5)

Therefore:

(6)

(7)

(8)

where:

is the new chassis dynamometer setting load, N;

is the adjustment road load, which is equal to , Nm;

is the simulated road load at reference speed , Nm;

is the target road load at reference speed , Nm;

, and are the new chassis dynamometer setting coefficients;

is the dynamic radius of the tyre on the chassis dynamometer, m, that is obtained by averaging the 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 m2, 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/s2. 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-1K-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 CO2 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**

Dilution air

filters

Vehicle

exhaust

Dilution tunnel

Heat exchanger

(optional)

Vent

MC

Flow meter and suction device

Mixing device

Dilution air

PDP, CFV, SSV, UFM

Connecting tube

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)**



Suction device

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)**

Heat

Exchanger

(

option

)

Ultrasonic

Flow Meter

Suction

Device

P

T

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.

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 m3/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), ± 0.03 kPa

Ambient temperature, ± 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, ± 1 min-1

Elapsed time for period (minimum 250 s), t ± 0.1 s

# Figure A5/6

# **PDP Calibration Configuration**

Manometer

Surge control valve (scrubber)

PPI

PPO

Revolutions

Elapsed time

n

t

Temperature indicator

PTI

PTO

Variable-flow restrictor

Laminar flow element, LFE

ETI

EPI

EDP

Filter

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, , at each test point shall be calculated in standard m3/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, , in m3/rev at absolute pump inlet temperature and pressure.

(1)

where:

is the pump flow rate at and ,m3/rev;

is the air flow at 101.325 kPa and 273.15 K (0 °C), m3/min;

is the pump inlet temperature, Kelvin (K);

is the absolute pump inlet pressure, kPa;

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, between the pump speed, , the pressure differential from pump inlet to pump outlet and the absolute pump outlet pressure shall be calculated as follows:

(2)

where:

is the correlation function;

is the pressure differential from pump inlet to pump outlet, kPa;

absolute outlet pressure , kPa.

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

(3)

(4)

,, and 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, 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 . Values of 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:

(5)

where:

is the flow, m³/min;

is the calibration coefficient;

is the absolute pressure, kPa;

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), ± 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, Qs ± 0.5 per cent,

CFV inlet depression, PPI ± 0.02 kPa,

Temperature at venturi inlet, ± 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**

Variable-flow restrictor

LFE

Thermometer

Filter

EDP

ETI

EPI

CFV

Tv

PPI

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, Qs 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:

(6)

where:

is the flow rate, m3/min at 273.15 K (0 °C) and 101.325, kPa;

is the temperature at the venturi inlet, Kelvin (K);

is the absolute pressure at the venturi inlet, kPa.

3.4.3.3.3.2. shall be plotted as a function of venturi inlet pressure. For sonic flow,  will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and decreases. These values of 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 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 , 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, , at each restriction setting (minimum 16 settings) shall be calculated in standard m3/s from the flow meter data using the manufacturer's prescribed method. The discharge coefficient, , shall be calculated from the calibration data for each setting as follows:

(7)

where:

QSSV is the airflow rate at standard conditions (101.325 kPa, 273.15 K (0 °C)), m3/s;

T is the temperature at the venturi inlet, Kelvin (K);

is the diameter of the SSV throat, m;

is the ratio of the SSV throat to inlet absolute static pressure, ;

is the ratio of the SSV throat diameter, dV, to the inlet pipe inner diameter ;

is the discharge coefficient of the SSV;

is the absolute pressure at venturi inlet, kPa.

To determine the range of subsonic flow, shall be plotted as a function of Reynolds number, , at the SSV throat. The Reynolds number at the SSV throat shall be calculated using the following equation:

(8)

where:

(9)

is 25.55152 in SI, ;

is the airflow rate at standard conditions (101.325 kPa, 273.15 K (0 °C)), m3/s;

is the diameter of the SSV throat, m;

is the absolute or dynamic viscosity of the gas, kg/ms;

is (empirical constant), kg/ms K0.5;

is 110.4 (empirical constant), Kelvin (K).

3.4.4.2.2. Because QSSV is an input to the Re equation, the calculations shall be started with an initial guess for QSSV or Cd of the calibration venturi, and repeated until QSSV 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 Cd from the resulting calibration curve fit equation shall be within ± 0.5 per cent of the measured Cd 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), ± 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, ± 0.5 per cent,

UFM inlet depression, ± 0.02 kPa,

Temperature at UFM inlet, ± 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**

Calibration flow meter (LFE, SSV)

Heater

UFM

Suction device

Including the necessary temperature and pressure sensors

P

T

Flow valve

The flow rate through the UFM can be set and controlled by speed control of the flow and/or flow valve

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, Qs, at each test point is calculated from the flow meter data using the manufacturer's prescribed method.

(10)

where:

is the air flow rate at standard conditions (101.325 kPa, 273.15 K (0 °C)), m3/s;

is the air flow rate of the calibration flow meter at standard conditions (101.325 kPa, 273.15 K (0 °C)), m3/s;

is the calibration coefficient.

For UFM systems without a heat exchanger, shall be plotted as a function of Tact.

The maximum variation in shall not exceed 0.3 per cent of the mean 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, CO2, or C3H8) 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, , 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, CO2, or C3H8).

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, FH, 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 NO2 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 NO2 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 NO2 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 (CO2) 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 (C1).

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 (C1).

4.1.4.5. Methane (CH4) 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 (C1).

4.1.4.6. Nitrogen oxide (NOx) 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 (NO2) 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 NOx converter bypassed (if installed).

4.1.4.8.1.3. The NO2 concentration shall be determined by subtracting the NO concentration from the NOx concentration in the CVS sample bags.

4.1.4.8.2. Measurement of NO2 from continuously diluted exhausts

4.1.4.8.2.1. A specific NO2 analyser (NDUV, QCL) may be used to measure the NO2 concentration continuously from diluted exhaust.

4.1.4.8.2.2. The analyser shall be calibrated (zeroed/ calibrated) in the NO2 mode using the NO2 certified concentration in the calibration gas cylinder.

4.1.4.9. Nitrous oxide (N2O) 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 N2O 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 (N2O) 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 CO2 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 (H2) analysis (where applicable)

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

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**

Dilution airfilters

Dilution air sample to:

- CVS bags

- PM sampling (optional)

- other devices

Vehicle exhaust

Dilution tunnel

HFID

Heat exchanger

(optional)

Vent

- CVS bag sampling

- other sampling systems

MC

Flow meter and suction device

Mixing device

Dilution air

PN

PDP, CFV, SSV, UFM

- continuous diluted exhaust analysers

- other sampling systems

- CVS bag sample (optional)

PM

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

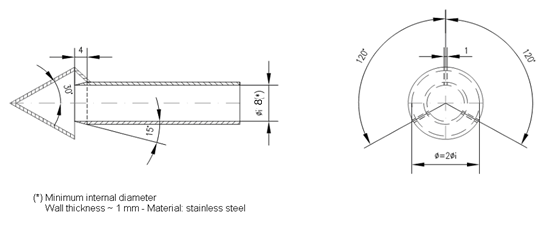
4.2.1.1. System overview

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**



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 () 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, , 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 () 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**



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.

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 mm2.

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.

Table A5/1

**Analytical Balance Verification Criteria**

| Measurement system | Intercept a0 | Slope a1 | Standard error SEE | Coefficient of determination r2 |
| --- | --- | --- | --- | --- |
| PM Balance | ≤ 1 µg | 0.99 – 1.01 | ≤ 1per cent max | ≥ 0.998 |

4.2.2.3. Elimination of static electricity effects

**The effects of static electricity shall be nullified. This may be achieved by grounding the balance through placement upon an antistatic mat and neutralization of the particulate filters prior to weighing using a polonium neutraliser or a device of similar effect. Alternatively, nullification of static effects may be achieved through equalization of the static charge.**

4.2.2.4. Buoyancy correction

The sample and reference filter weights shall be corrected for their buoyancy in air. The **buoyancy correction is a function of sampling filter density, air density and the density of the balance calibration** weight, and does not account for the buoyancy of the 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/m3;

(b) PTFE membrane filter: 2,144 kg/m3;

(c) PTFE membrane filter with polymethylpentene support ring: 920 kg/m3.

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:

(11)

where:

is the corrected particulate mass, mg;

is the uncorrected particulate mass, mg;

is the density of the air, kg/m3;

is the density of balance calibration weight, kg/m3;

is the density of the particulate sampling filter, kg/m3.

The density of the air shall be calculated as follows:

(12)

is the total atmospheric pressure, kPa;

is the air temperature in the balance environment, Kelvin (K);

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, , 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 () shall be calculated as follows:

(13)

where:

is the upstream particle number concentration for particles of diameter ;

is the downstream particle number concentration for particles of diameter ;

is the particle electrical mobility diameter (30, 50 or 100 nm).

and shall be corrected to the same conditions.

The mean particle concentration reduction, , at a given dilution setting shall be calculated as follows:

(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 (CH3(CH2)38CH3) particles, with an inlet concentration of ≥ 10,000 per cm³, 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 t90 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 t90 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**



OT

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: PND1 and PND2) 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:  CO2/H2O interference | Monthly | -1 to 3 ppm |
| NOx converter check | Monthly | > 95 per cent |
| CH4 cutter check | Yearly | 98 per cent of Ethane |
| FID CH4 response | Yearly | See paragraph 5.4.3. |
| FID air/fuel flow | At major maintenance | According to instrument mfr. |
| NO/NO2 NDUV:  H2O, 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 N2 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, , for a particular hydrocarbon compound is the ratio of the FID C1 reading to the gas cylinder concentration, expressed as ppm C1.

The concentration of the test gas shall be at a level to give a response of approximately 80 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:

Propylene and purified air:

Toluene and purified air:

These are relative to an of 1.00 for propane and purified air.

5.5. NOx 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 NO2 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 NO2 concentration of the gas mixture shall be less than 5 per cent of the NO concentration). The NOx 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 NOx analyser shall then be switched to the NOx mode, whereby the gas mixture (consisting of NO, NO2, O2 and N2) 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

**NOx Converter Efficiency Test Configuration**



5.5.1.6. With the ozonator deactivated, the flow of oxygen or synthetic air shall be shut off. The NO2 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 NOx 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:

(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 PNC.

# 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 r2, 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, , 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, , 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, , shall be calculated as follows:

(16)

where:

is the upstream particle number concentration for particles of diameter ;

is the downstream particle number concentration for particles of diameter ;

is the particle electrical mobility diameter (30, 50 or 100 nm).

and shall be corrected to the same conditions.

The mean particle concentration reduction factor, , at a given dilution setting shall be calculated as follows:

(17)

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

(18)

where:

is the upstream particle number concentration;

is the downstream particle number concentration.

5.7.2.3. The VPR shall demonstrate greater than 99.0 per cent removal of tetracontane (CH3(CH2)38CH3) 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 CO2, ≤ 0.1 ppm NO, < 0.1 ppm NO2, <0.1 ppm N2O, <0.1 ppm NH3;

6.1.2.2. Synthetic air:

Purity: ≤1 ppm C1, ≤1 ppm CO, ≤400 ppm CO2, ≤0.1 ppm NO; oxygen content between 18 and 21 per cent volume;

6.1.2.3. Oxygen:

Purity: > 99.5 per cent vol. O2;

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) C3H8 in synthetic air (see paragraph 6.1.2.2. above);

(b) CO in nitrogen;

(c) CO2 in nitrogen;

(d) CH4 in synthetic air;

(e) NO in nitrogen (the amount of NO2 contained in this calibration gas shall not exceed 5 per cent of the NO content);

(f) NO2 in nitrogen (tolerance ± 2 per cent);

(g) N2O in nitrogen (tolerance ± 2 per cent);

(h) C2H5OH in synthetic air or nitrogen (tolerance ± 2 per cent).

7. Additional sampling and analysis methods

7.1. Fourier transform infrared (FTIR) analyser for NH3 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.

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 NH3 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.

7.1.1.4. Measurement cross interference

7.1.1.4.1. The spectral resolution of the target wavelength shall be within 0.5 per cmin 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 CO2 and H2O 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:

(19)

where:

Flow\_lost\_max is the maximum return by-pass flow, volume/sec;

Vmix is the volume of diluted exhaust per phase;

DF is the dilution factor.

7.2. Sampling and analysis methods for N2O

7.2.1. Gas chromatographic method

7.2.1.1. General description

Followed by gas chromatographic separation, N2O shall be analysed by an appropriate detector. This shall be an electron capture detector (ECD).

7.2.1.2. Sampling

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 single composite dilution background sample can be analysed (not possible for phase weighing).

7.2.1.2.1. Sample transfer

Secondary sample storage media may be used to transfer samples from the test cell to the GC lab. Good engineering judgement shall be used to avoid additional dilution when transferring the sample from sample bags to secondary sample bags.

7.2.1.2.1.1. Secondary sample storage media.

Gas volumes shall be stored in sufficiently clean containers that off-gas minimally or allow permeation of gases. Good engineering judgment shall be used to determine acceptable thresholds of storage media cleanliness and permeation. In order to clean a container, it may be repeatedly purged, evacuated and heated.

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 N2O 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 N2O 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 N2O 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 N2 or Ar/CH4

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.

7.2.1.9. Limit of detection, limit of quantification

The detection limit is based on the noise measurement close to the retention time of N2O (reference DIN 32645, 01.11.2008):

Limit of Detection: (20)

where is considered to be equal to noise.

Limit of Quantification: (21)

For the purpose of calculating the mass of N2O, 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]

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, CO2 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. Ri1 to Ri3 describe the final measurement results of three tests to determine gaseous compounds, particulate matter, particle number, CO2 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 CO2 value shall be calculated.

Figure A6/1

**Flowchart for the Number of Type 1 Tests**

no

First Test

no

Second Test

and

and

or

and

Third Test

and

and

no

no

no

no

and

or

no

yes

yes

yes

yes

yes

yes

yes

yes

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 CO2 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 g/m3 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 cm³ ) scaled from the particle concentration reduction factor (PCRF) and the CVS flow rate used in the actual test;

1.2.1.3.2.1.2. Either the 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 cm³ 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 H2O/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:

(g H2O/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 CO2 interpolation 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 CO2 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. CO2 interpolation range

The CO2 interpolation method shall only be used if the difference in CO2 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 CO2 for vehicle H, whichever value is the lower.

At the request of the manufacturer and with approval of the responsible authority, the CO2 interpolation line may be extrapolated to a maximum of 3 g/km above the CO2 emission of vehicle H and/or below the CO2 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, CO2 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, CO2 emissions, and fuel consumption. Best and worst case modes shall be identified by the evidence provided on the CO2 emissions and fuel consumption in all modes. CO2 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 CO2/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 CO2 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 cm³.

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 cm³. Upon removal of the filter, the particle counter shall show an increase in measured concentration to at least 100 particles per cm³ when sampling ambient air and a return to ≤ 0.2 particles per cm³ 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 PND1 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.

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

(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 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 High2 phase may be excluded for determining the regenerative factor, , for Class 2 vehicles.

1.6. At the option of the Contracting Party, the Extra High3 phase may be excluded for determining the regenerative factor, , 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 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 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, , 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.

2.2.6. The emission values during regeneration, , for each compound i shall be calculated according to paragraph 3. below. The number of operating cycles, , measured for complete regeneration shall be recorded.

3. Calculations

3.1. Calculation of the exhaust and CO2 emissions, and fuel consumption of a single regenerative system

(1)

(2)

(3)

where for each compound i considered:

are the mass emissions of compound i over test cycle j without regeneration, g/km;

are the mass emissions of compound i over test cycle j during regeneration, g/km (if , the first WLTC test shall be run cold and subsequent cycles hot);

are the mean mass emissions of compound i without regeneration, g/km;

are the mean mass emissions of compound i during regeneration, g/km;

are the mean mass emissions of compound i, g/km;

is the number of test cycles, between cycles where regenerative events occur, during which emissions measurements on Type 1 WLTCs are made, ≥ 1;

is the number of complete operating cycles required for regeneration;

is the number of complete operating cycles between two cycles where regeneration events occur.

The calculation of 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 for each compound i considered.

The manufacturer may elect to determine for each compound independently either additive offsets or multiplicative factors.

factor: (4)

offset: (5)

, and results, and the manufacturer’s choice of type of factor shall be recorded.

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 CO2 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 CO2 emissions and fuel consumption.

for (6)

(7)

(8)

(9)

(10)

(11)

factor: (12)

offset: (13)

where:

are the mean mass emissions of all events k of compound i)without regeneration, g/km;

are the mean mass emissions of all events k of compound i during regeneration, g/km;

are the mean mass emission of all events k of compound i, g/km;

are the mean mass emissions of event k of compound i without regeneration, g/km;

are the mean mass emissions of event k of compound i during regeneration, g/km;

are the mass emissions of event k of compound i in g/km without regeneration measured at point j where , g/km;

are the mass emissions of event k of compound i during regeneration (when , the first Type 1 test is run cold, and subsequent cycles are hot) measured at operating cycle j where , g/km;

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;

is the number of complete operating cycles of event k required for complete regeneration;

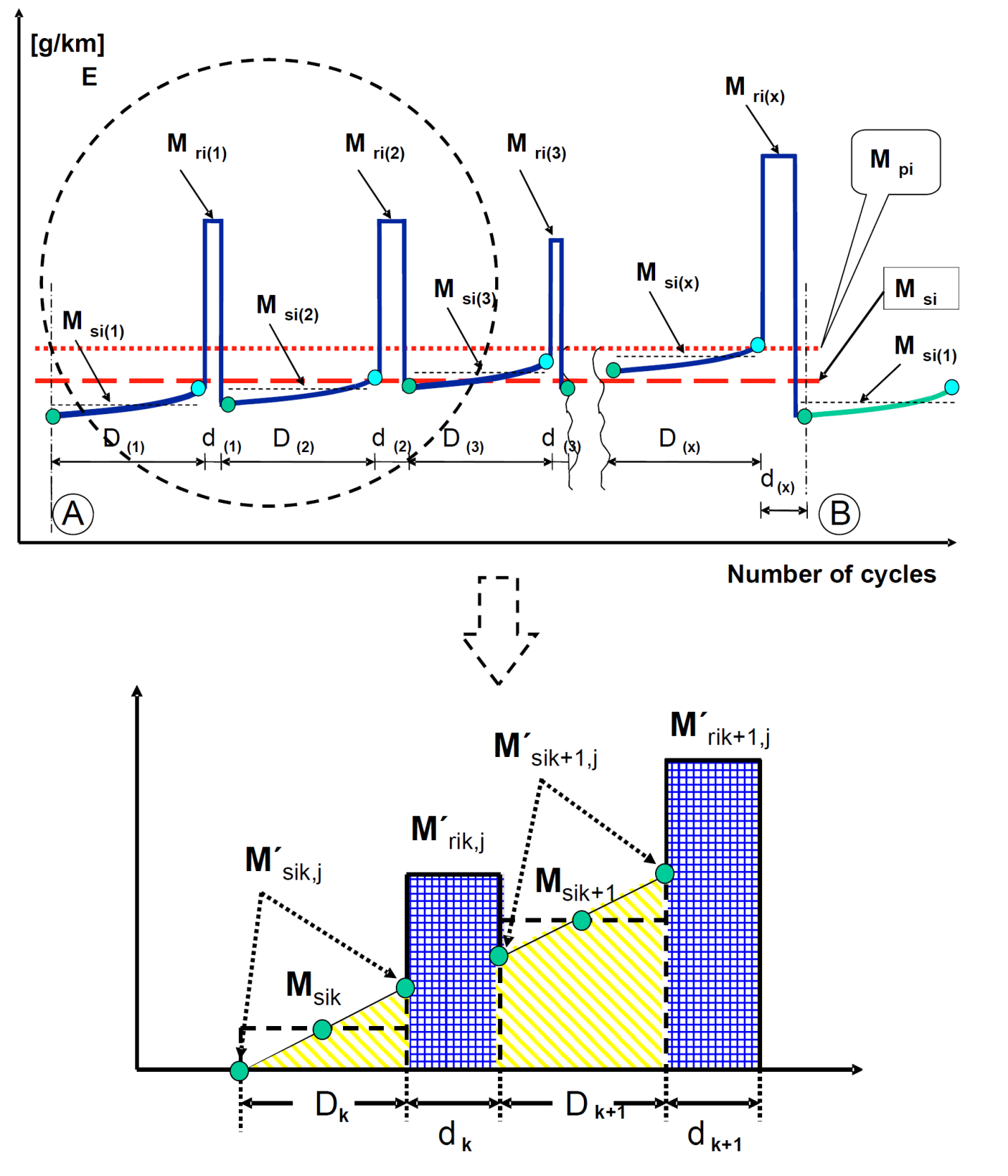
is the number of complete operating cycles of event k between two cycles where regenerative phases occur;

is the number of complete regeneration events.

The calculation of 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 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 CO2 emissions (g/km) as a function of the energy balance for the vehicle batteries.

The corrected values for fuel consumption and CO2 emissions shall correspond to a zero energy balance (), 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.

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 shall be logged over the cycle phases required to be driven for the applicable vehicle class.

3.4. and 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 and 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) as calculated from the test result corresponds to REESS charging;

(c) as calculated from the test result corresponds to REESS charging and discharging. , expressed as a percentage of the energy content of the fuel consumed over the cycle, is calculated in the equation below:

(1)

where:

is the change in the REESS energy content, per cent;

is the nominal REESS voltage, V;

RCB is REESS charging balance over the whole cycle, Ah;

is the energy content of the consumed fuel, MJ.

is lower than the RCB correction criteria according to the equation below and Table A6.App2/1 below :

(2)

Table A6.App2/1

**RCB Correction Criteria**

| Cycle | WLTC city(low + medium) | WLTC (low + medium + high) | WLTC(low + medium + high + extra high) |
| --- | --- | --- | --- |
| RCB correction criterion (%) | 1.5 | 1 | 0.5 |

4. Correction Method

4.1. To apply the correction function, the electric power to the battery shall be calculated from the measured current and the nominal voltage value for each phase of the WLTC test: (3)

where:

is the change in the electrical REESS energy content of phase i, MJ;

is the nominal REESS voltage, V;

is the electric current in phase (i), A;

is the time at the end of phase (i), seconds (s).

4.2. For correction of fuel consumption, l/100 km, and CO2 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: (4)

where:

is the resulting fuel consumption difference of phase (i), l;

is the change in the electrical REESS energy content of phase (i), MJ;

is the efficiency of the alternator;

is the combustion process specific Willans factor as defined in Table A6.App2/2.

4.4. The resulting CO2 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: (5)

where:

is the resulting CO2 emission difference of phase (i), g;

is the change in the electrical REESS energy content of phase (i), MJ;

is the efficiency of the alternator;

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:

4.6. The consumption difference of the engine for the WLTC test is the sum over the (i) single phases as shown below:

(6)

where:

is the change in consumption over the whole cycle, l.

4.7. The CO2 emissions difference of the engine for the WLTC test is the sum over the (i) single phases as shown below:

(7)

where:

is the change in CO2-emission over the whole cycle, g.

4.8. For correction of the fuel consumption, l/100 km, and CO2 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 |
| gCO2/MJ | 175 | 186 |
| Petrol (E5) | l/MJ | 0.0744 | 0.0789 |
| gCO2/MJ | 174 | 185 |
| Petrol (E10) | l/MJ | 0.0756 | 0.0803 |
|  | gCO2/MJ | 174 | 184 |
| CNG (G20) | m³/MJ | 0.0719 | 0.0764 |
| gCO2/MJ | 129 | 137 |
| LPG | l/MJ | 0.0950 | 0.101 |
| gCO2/MJ | 155 | 164 |
| E85 | l/MJ | 0.102 | 0.108 |
| gCO2/MJ | 169 | 179 |
| Compression ignition | Diesel (B0) | l/MJ | 0.0611 | 0.0611 |
| gCO2/MJ | 161 | 161 |
| Diesel (B5) | l/MJ | 0.0611 | 0.0611 |
| gCO2/MJ | 161 | 161 |
|  | Diesel (B7) | l/MJ | 0.0611 | 0.0611 |
|  |  | gCO2/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 NOx correction factor, , shall be rounded to two decimal places.

1.5. The dilution factor, , 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:

(1)

where:

is the volume of the diluted gas, in litres per test (prior to correction);

is the volume of gas delivered by the positive displacement pump in testing conditions, litres per pump revolution;

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:

(2)

where:

(3)

is the test room barometric pressure, kPa;

is the vacuum at the inlet to the positive displacement pump relative to the ambient barometric pressure, kPa;

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, 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)  g/l

Carbon dioxide (CO2)  g/l

Hydrocarbons:

for petrol (E0) (C1H1.85)  g/1

for petrol (E5) (C1H1.89O0.016)  g/1

for petrol (E10) (C1H1.93 O0.033)  g/l

for diesel (B0) (C1Hl.86)  g/1

for diesel (B5) (C1Hl.86O0.005)  g/1

for diesel (B7) (C1H1.86O0.007)  g/l

for LPG (C1H2.525)  g/l

for NG/biomethane (CH4)  g/l

for ethanol (E85) (C1H2.74O0.385)  g/l

Nitrogen oxides (NOx)  g/1

Nitrogen dioxide (NO2)  g/1

Nitrous oxide (N2O)  g/1

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 CXHYOZ is as follows:

(4)

where:

ρTHC is the density of total hydrocarbons and non-methane hydrocarbons, g/l;

MWC is the molar weight of carbon (12.011 g/mol);

MWH is the molar weight of hydrogen (1.008 g/mol);

MWO is the molar weight of oxygen (15.999 g/mol);

VM 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 CXHYOZ;

O/C is the oxygen to carbon ratio for a specific fuel CXHYOZ.

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, Mi per test shall be calculated as follows:

(5a)

If the number of phases, n, per test is >1, Mi per test shall be calculated as follows:

(5b)

(5c)

(In this case Vmix, KH, ci, and d of the corresponding phase shall be used.)

where:

is the mass emission of compound i per test or phase, g/km;

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);

is the density of compound i in grams per litre at standard temperature and pressure (273.15 K (0 °C) and 101.325 kPa);

is a humidity correction factor applicable only to the mass emissions of oxides of nitrogen (NO2 and NOx) per test or phase;

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;

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:

(6)

where:

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;

is the measured concentration of gaseous compound (i) in the diluted exhaust gas, ppm;

is the concentration of gaseous compound (i) in the dilution air, ppm;

is the dilution factor.

3.2.1.1.1. The dilution factor, , shall be calculated as follows:

for petrol (E0, E5, E10) and diesel (B0) (7a)

for diesel (B5 and B7) (7b)

for LPG (7c)

for NG/biomethane (7d)

for ethanol (E85) (7e)

for hydrogen (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 Vmix by the sum of each phase's Vmix.

3.2.1.1.2. The general equation for calculating the dilution factor , DF, for each reference fuel with an average composition of CxHyOz is as follows:

(8)

where:

(9)

:

is the concentration of CO2 in the diluted exhaust gas contained in the sample bag, per cent volume;

is the concentration of HC in the diluted exhaust gas contained in the sample bag, ppm carbon equivalent;

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:

(10)

where:

is the corrected concentration of NMHC in the diluted exhaust gas, ppm carbon equivalent;

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;

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;

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 CH4 and NMHC shall be calculated as follows:

(11)

(12)

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

(13)

(14)

where:

is the HC concentration with sample gas flowing through the NMC, ppm C;

is the HC concentration with sample gas bypassing the NMC, ppm C;

is the methane response factor as determined per paragraph 5.4.3.2. of Annex 5;

is the methane efficiency as determined per paragraph 3.2.1.1.3.3.1. below;

is the ethane efficiency as determined per paragraph 3.2.1.1.3.3.2. below.

If  < 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:

(15)

where:

is the HC concentration with CH4 flowing through the NMC, ppm C;

is the HC concentration with CH4 bypassing the NMC, ppm C.

3.2.1.1.3.3.2. Ethane conversion efficiency, EE

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:

(16)

where:

is the HC concentration with C2H6 flowing through the NMC, ppm C;

is the HC concentration with C2H6 bypassing the NMC,  ppm C.

If the ethane conversion efficiency of the NMC is 0.98 or above, EE 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 EM is 0.

Equation 13 from above becomes:

(17)

Equation 14 from above becomes:

(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, , 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:

(19)

where:

is the flow-weighted average concentration;

is the CVS flow rate at time , m³/min;

is the concentration at time , ppm;

sampling interval, seconds (s);

total CVS volume, m³.

3.2.1.2. Calculation of the NOx humidity correction factor

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

(20)

where:

(21)

and:

is the specific humidity, grams of water vapour per kilogram dry air;

is the relative humidity of the ambient air, per cent;

is the saturation vapour pressure at ambient temperature, kPa;

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 NO2 concentration from NO and NOx

NO2 shall be determined by the difference between NOx 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:

(22)

where:

is the integral of the recording of the continuous dilute NO analyser over the test (t2-t1);

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. NO2 concentrations

3.2.1.3.2.1. Determination NO2 concentration from direct diluted measurement

3.2.1.3.2.2. NO2 concentrations shall be calculated from the integrated NO2 analyser reading, corrected for varying flow if necessary.

3.2.1.3.2.3. The average NO2 concentration shall be calculated as follows:

(23)

where:

is the integral of the recording of the continuous dilute NO2 analyser over the test (t2-t1);

is the concentration of NO2 measured in the diluted exhaust, ppm.

3.2.1.3.2.4. Dilution air concentration of NO2 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:

(24)

where:

is the integral of the recording of the heated FID over the test (t1 to t2);

is the concentration of HC measured in the diluted exhaust in ppm of and is substituted for 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 CO2 calculations for individual vehicles in an interpolation family

3.2.3.1. Fuel consumption and CO2 emissions without using the interpolation method

The CO2 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 CO2 interpolation method shall not be applicable.3.2.3.2. Fuel consumption and CO2 emissions using the interpolation method

The CO2 emissions and the fuel consumption for each individual vehicle in the interpolation family may be calculated according to the CO2 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 CO2 emissions of test vehicles L and H

The mass of CO2 emissions, , 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 and 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 FCL,p and FCH,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.

TMind ,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.

If the same test mass is used for test vehicles L and H, the value of 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, RRL, and test vehicle H, RRH, 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:

(25)

where:

is the rolling resistance of the front axle tyres, kg/tonne;

is the rolling resistance of the rear axle tyres, kg/tonne;

is the percentage of the vehicle mass on the front axle;

represents vehicle L, H or an individual vehicle.

For the tyres fitted to an individual vehicle, the value of the rolling resistance 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 for the interpolation method shall be set to .

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, Δ(CD×Af), between vehicles L, H and/or an individual vehicle shall be determined with an accuracy of 0.015 m².

Δ(CD×Af) may be calculated according to the following equation maintaining the accuracy of 0.015 m² also for the sum of options and body shapes:

(26)

where:

is the aerodynamic drag coefficient;

is the frontal area of the vehicle, m2;

is the number of options on the vehicle that are different between an individual vehicle and test vehicle L.

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, m2;

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, m2;

The sum of all Δ(CD×Af)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 Δ(CD×Af)LH.

The increase or decrease of the aerodynamic drag expressed as Δ(CD×Af) 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 Δ(CD\*Af)LH, defined below, shall be set to zero, if:

(a) the wind tunnel facility is not able to accurately determine Δ(CD\*Af);

(b) there are no drag influencing options between the test vehicles H and L that shall be included in the interpolation method.

Δ(CD\*Af)LH, m², is the difference in aerodynamic drag of the test vehicle H compared to test vehicle L and shall be recorded.

3.2.3.2.2.4. Calculation of road load for individual vehicles in the CO2 interpolation family

The road load coefficients , and (as defined in Annex 4) for test vehicles H and L are referred to as , and ,and , and respectively. An adjusted road load curve for the test vehicle L is defined as follows:

(27)

Applying the least squares regression method in the range of the reference speed points, adjusted road load coefficients and shall be determined for with the linear coefficient set to . The road load coefficients , and for an individual vehicle in the CO2 interpolation family are calculated as follows:

(28)

or, if = 0, equation 29 below shall apply:

(29)

(30)

(31)

or, if = 0, equation 32 below shall apply:

(32)

where:

(33)

(34)

3.2.3.2.3. Calculation of cycle energy per phase

The cycle energy demand, and distance, per cycle phase, p, applicable for individual vehicles in the CO2 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: (35)

(test vehicle L)

k=2: (36)

(test vehicle H)

k=3: (37)

(an individual vehicle in the CO2 interpolation family)

3.2.3.2.4..3.. Calculation of the CO2 value for an individual vehicle using the CO2 interpolation method

For each cycle phase, p, of the WLTC applicable for individual vehicles in the CO2 interpolationfamily, the contribution to the total mass of CO2 for an individual vehicle shall be calculated as follows:

(38)

The terms E1,p, E2,p and E3,p are defined in paragraph 3.2.3.2.3. above.

The CO2 mass emissions attributed to an individual vehicle of the CO2 interpolation family, , shall be calculated by the following equation for all of the applicable cycle phases, p:

(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 CO2 interpolation family, the contribution to the FC for an individual vehicle shall be calculated as follows:

The terms E1,p, E2,p and E3,p are defined in paragraph 3.2.3.2.3. above.

The fuel consumption, FCind, attributed to an individual vehicle of the CO2 interpolation family, FCind, shall be calculated for all applicable cycle phases using the following equation:

.

3.3 Mass of particulate emissions

3.3.1. Calculation of particulate emissions

Particulate emission (g/km) is calculated as follows:

(40)

where exhaust gases are vented outside tunnel;

and:

(41)

where exhaust gases are returned to the tunnel;

where:

is the volume of diluted exhaust gases (see paragraph 2. of this Annex), under standard conditions;

is the volume of diluted exhaust gas flowing through the particulate filter under standard conditions;

is the mass of particulate matter collected by one or more filters, mg;

is the distance corresponding to the operating cycle, km.

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:

(42)

in the case where exhaust gases are vented outside tunnel;

(43)

in the case where exhaust gases are returned to the tunnel;

where:

is the volume of tunnel air flowing through the background particulate filter under standard conditions;

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; ;

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

(44)

where:

is the volume of diluted exhaust gas flowing through the particulate filter under standard conditions;

is the volume of the double diluted exhaust gas passing through the particulate collection filters under standard conditions;

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.:

(45)

where:

is the measured volume of diluted exhaust gas in the dilution system following extraction of the particulate sample under standard conditions.

4. Determination of particle numbers

4.1. The number of particle emissions shall be calculated by means of the following equation:

(46)

where:

is the particle number emission, particles per kilometre;

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);

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;

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, , 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, ;

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);

is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the test;

is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the background measurement;

is the distance corresponding to the operating cycle, km

shall be calculated from the following equation:

(47)

where:

is a discrete measurement of particle concentration in the diluted gas exhaust from the particle counter; particles per cubic centimetre and corrected for coincidence;

is the total number of discrete particle concentration measurements made during the operating cycle and shall be calculated using the following equation:

(48)

where:

is the time duration of the operating cycle, s;

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 ∆t 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 over the corresponding cycle time between tstart and tend according to the following equation:

(49)

where:

if (50)

if (51)

and:

tstart is the time at which the applicable cycle or phase starts, s;

tend is the time at which the applicable cycle or phase ends, s;

is the energy demand during time period (i-1) to (i), Ws;

is the driving force during time period (i-1) to (i), N;

is the distance travelled during time period (i-1) to (i), m.

(52)

where:

is the driving force during time period (i-1) to (i), N;

is the target velocity at time ti, km/h;

is the test mass, kg;

is the acceleration during time period (i-1) to (i), m/s²;

, , are the road load coefficients for the test vehicle under consideration (, or ) in N, N/km/h and in N/(km/h)² respectively.

(53)

where:

is the distance travelled in time period (i-1) to (i), m;

is the target velocity at time , km/h;

is time, s.

(54)

where:

is the acceleration during time period (i-1) to (i), m/s²;

is the target velocity at time , km/h;

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.

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)

(55a)

6.4. For a vehicle with a positive ignition engine fuelled with petrol (E5)

(55b)

6.5. For a vehicle with a positive ignition engine fuelled with petrol (E10)

(55c)

6.6. For a vehicle with a positive ignition engine fuelled with LPG

(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:

(55e)

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

(55f)

where:

is the actual H/C ratio of the fuel used.

6.7. For a vehicle with a positive ignition engine fuelled with NG/biomethane

(55g)

6.8. For a vehicle with a compression engine fuelled with diesel (B0)

(55h)

6.9. For a vehicle with a compression engine fuelled with diesel (B5)

(55i)

6.10. For a vehicle with a compression engine fuelled with diesel (B7)

(55j)

6.11. For a vehicle with a positive ignition engine fuelled with ethanol (E85)

(55k)

;

6.12. Fuel consumption for any test fuel may be calculated using the following equation:

(56)

6.13. Fuel consumption for vehicles fuelled by gaseous hydrogen:

(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.

(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 CXHYOZ;

O/C is the oxygen to carbon ratio of a specific fuel CXHYOZ;

MWC is the molar weight of carbon (12.011 g/mol);

MWH is the molar weight of hydrogen (1.008 g/mol);

MWO is the molar weight of oxygen (15.999 g/mol);

ρfuel 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;

CO2 are the measured emissions of carbon dioxide, g/km;

H2O are the measured emissions of water, g/km;

H2 are the measured emissions of hydrogen, g/km;

p1 is the gas pressure in the fuel tank before the operating cycle, Pa;

p2 is the gas pressure in the fuel tank after the operating cycle, Pa;

T1 is the gas temperature in the fuel tank before the operating cycle, K;

T2 is the gas temperature in the fuel tank after the operating cycle, K;

Z1 is the compressibility factor of the gaseous fuel at p1 and T1;

Z2 is the compressibility factor of the gaseous fuel at p2 and T2;

V is the interior volume of the gaseous fuel tank, m³.

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 ∆EREESS of all rechargeable electric energy storage systems (REESS), i.e. the sum of the RCB values multiplied by the respective nominal VREESS 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 |
| RCDA | km | Rounded to nearest whole number |
| RCDC | 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 |
| EAC recharge energy from the grid | Wh | Rounded to nearest whole number |
| FC correction factor | l/100 km/(Wh/km) | Rounded to 4 significant digits |
| CO2 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 (Low3), a medium phase (Medium3-1), a high phase (High3-1) and an extra high phase (Extra High3).

1.5.1.1.1.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low3), a medium phase (Medium3-2), a high phase (High3-2) and an extra high phase (Extra High3).

1.5.1.1.1.3. At the option of the Contracting Party, the Extra High3 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 (Low3) and a medium phase (Medium3-1)

1.5.1.1.2.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low3) and a medium phase (Medium3-2)

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 (Low3), a medium phase (Medium3-1), a high phase (High3-1) and an extra high phase (Extra High3).

1.5.1.2.1.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low3), a medium phase (Medium3-2), a high phase (High3-2) and an extra high phase (Extra High3).

1.5.1.2.1.3. At the option of the Contracting Party, the Extra High3 phase may be excluded.

Table A8/3

**Test Matrix**

|  | | WLTP | | WLTP city |
| --- | --- | --- | --- | --- |
| Criteria Emissions, FC, CO2, AER, EAER, RCDC, RCDA, EAC | Criteria Emissions, FC, CO2 | AERcity, EACcity |
| Charge-depleting | Charge-sustaining | Charge-depleting |
| OVC-HEV | Class 3a | Low3 + Medium3-1 + High3-1 + (Extra High3) | Low3 + Medium3-1 + High3-1 + (Extra High3) | Low3 + Medium3-1 |
| Class 3b | Low3 + Medium3-2 + High3-2 + (Extra High3) | Low3 + Medium3-2 + High3-2 + (Extra High3) | Low3 + Medium3-2 |
| NOVC-HEV | Class 3a | -- | Low3 + Medium3-1 + High3-1 + (Extra High3) | -- |
| Class 3b | -- | Low3 + Medium3-2 + High3-2 + (Extra High3) | -- |
| PEV | Class 3a | Low3 + Medium3-1 + High3-1 + (Extra High3) | -- | Low3 + Medium3-1 |
| Class 3b | Low3 + Medium3-2 + High3-2 + (Extra High3) | -- | Low3 + Medium3-2 |

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 CD test shall be performed in the highest electric energy consumption mode that best matches the driving cycle. If the vehicle cannot follow the trace, other installed propulsion systems shall be used to allow the vehicle to best follow the cycle.

3.2.4.2.2.2. Dedicated driver-selectable modes such as "mountain mode" or "maintenance mode" which are not intended for normal daily operation but only for special limited purposes shall not be considered for CD condition testing.

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 ignition switch shall be in the "OFF" position, and the REESS shall not be recharged from an external electric energy source. The RCB instrumentation shall not be turned off between test cycle phases. In the case of ampere-hour meter measurement, the integration shall remain active throughout the entire test until the test is concluded.

Restarting after soak, the vehicle shall be operated in the required driver-selectable operation mode.

3.2.4.3.3. In deviation from paragraph 5.3.1. of 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, , as shown in the equation below is less than 4 per cent.

(1)

where:

is the net energy change, per cent;

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, EAC, 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 Annex6.

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, CO2, 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, RCDC

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 (RCDA)

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, CO2 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, EAC, 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.

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, , from the CD and CS test results shall be calculated using the equation below:

(2)

where:

is the utility factor-weighted exhaust emissions of each measured emission compound, g/km;

is the emissions compound;

is the fractional utility factor of the jth phase;

are the compound mass emissions measured during the jth CD phase, g/km;

are the compound mass emissions for the CS test according to paragraph 3.2.5., g/km;

is the index number of the phases up to the end of the transition cycle n;

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.

4.1.2.2. The charging balance correction (RCB) calculation is not required for the determination of emission compounds.

4.2. CO2 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 CO2 emissions

The CO2 values at charge-depleting, , shall be calculated as follows:

(3)

where:

is the utility factor-adjusted mass of CO2 emissions during CD mode, g/km;

are the CO2 emissions measured during the jth CD phase, g/km;

is the driving cycle and phase-specific utility factor according to Appendix 5 to this Annex;

is the index number of each phase up to the end of the transition cycle n;

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, , at CD shall be calculated as follows:

(4)

where:

is the utility factor-adjusted fuel consumption CD mode, l/100 km;

is the fuel consumption measured during the jth CD phase, l/100 km;

is the driving cycle and phase-specific utility factor according to Appendix 5 to this Annex;

is the index number of each phase up to the end of the transition cycle n;

is the number of phases driven up to the end of transition cycle n.

4.2.1.3. Charge-sustaining fuel consumption and CO2 emissions

4.2.1.3.1. Test result correction as a function of REESS charging balance

The corrected values and shall correspond to a zero charging balance (), 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 and if any of the following cases apply:

(a) The manufacturer can prove that there is no relation between the energy balance and CO2 emissions/fuel consumption;

(b) as calculated from the test result corresponds to REESS charging,

(c) as calculated from the test result corresponds to REESS discharging.

, expressed as a percentage of the energy content of the fuel consumed over the cycle, shall be calculated using the equation below:

(5)

where:

is the change in the REESS energy content, per cent;

is the nominal REESS voltage, V;

is REESS charging balance over the whole cycle, Ah;

is the energy content of the consumed fuel, MJ.

is lower than or equal to the RCB correction criteria, according to the equation below and Table A8/5:

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 CO2 emissions

The weighted CO2 emissions from the CD and CS test results shall be calculated using the equation below:

(6)

where:

are the utility factor-weighted CO2 emissions, g/km;

is the fractional utility factor of the jth phase;

are the CO2 emissions measured during the jth CD phase, g/km;

are the CO2 emissions for the CS test according to paragraph 4.2.1.3. above, g/km;

is the index number of each phase up to the end of the transition cycle n;

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:

(7)

where:

is the utility factor-weighted fuel consumption, l/100 km;

is the fractional utility factor of the jth phase;

is the fuel consumption measured during the jth CD phase, l/100 km;

is the fuel consumption measured during the CS test according to paragraph 4.2.1.3. above, l/100 km;

is the index number of each phase up to the end of the transition cycle n;

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 CO2 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, and , shall correspond to a zero energy balance (), 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 and 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) as calculated from the test result corresponds to REESS charging;

(c) as calculated from the test result corresponds to REESS discharging.

, expressed as a percentage of the energy content of the fuel consumed over the cycle, shall be calculated using the equation below:

(8)

where:

is the nominal REESS voltage for ith REESS, V;

is the charging balance over the whole cycle for the ith REESS, Ah;

is the energy content of the consumed fuel, MJ;

index of REESS;

number of installed REESS.

is less than or equal to the RCB correction criteria, according to the following equation and Table A8/6 :

Table A8/6

**RCB Correction Criteria**

| Cycle |  | WLTC  (Low + Medium + High) | WLTC  (Low + Medium + High + Extra High) |
| --- | --- | --- | --- |
| RCB correction criterion (%) |  | 1 | 0.5 |

4.2.2.3.3. Where RCB corrections of CO2 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:

(9)

(10)

where:

is the utility factor-weighted total energy consumption, Wh/km;

is the driving cycle and phase-specific utility factor according to Appendix 5 to this Annex;

is the calculated fraction of EAC used in the jth phase during the CD test, Wh/km;

is the measured charge balance of the traction REESS of the jth phase during the CD test, Ah;

is the distance driven in the jth phase during the CD test,km;

is the measured recharged electric energy from the mains, Wh;

is the index number of each phase up to the end of transition cycle n;

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:

(11)

where:

is the electric energy consumption, Wh/km;

is the recharged electric energy from the mains, Wh;

is the equivalent all-electric range according to paragraph 4.4.1.2. below, km.

4.3.1.3. CD AC electric energy consumption, , including charging losses

(12)

where:

is the recharged electric energy from the grid including charging losses, Wh;

is the electric energy consumption, Wh/km;

is the driving cycle and phase-specific utility factor according to Appendix 5 to this Annex;

is the index number of each phase up to the end of transition cycle n;

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:

(13)

where:

is the electric energy consumption, Wh/km;

is the recharged electric energy from the mains, Wh;

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:

(14)

where:

(15)

and:

is the equivalent all-electric range EAER, km;

are the CO2 emissions during the CS test, g/km;

are the CO2 emissions in the jth phase during the CD test, g;

is the distance driven in the jth phase during the CD test, km;

is the CD cycle range, km;

is the index number of each phase up to the end of the transition cycle n;

is the number of phases driven up to the end of the transition cycle n. .

4.4.1.3. Charge-depleting cycle range (

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 shall include those transition cycles or cycles.

4.4.1.4. Actual charge-depleting cycle range ()

(16)

where:

is the actual CD range, km;

are the CO2 emissions during the CS test, g/km;

are the CO2 emissions over the nth drive cycle in CD operating condition, g/km;

are the average CO2 emissions in CD operating condition until the n-1th drive cycle, g/km;

is the test distance travelled during jth drive cycle, km;

is the test distance travelled during the nth drive cycle in CD operating condition, km;

is the index number of each whole cycle up to the end of the transition cycle 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]

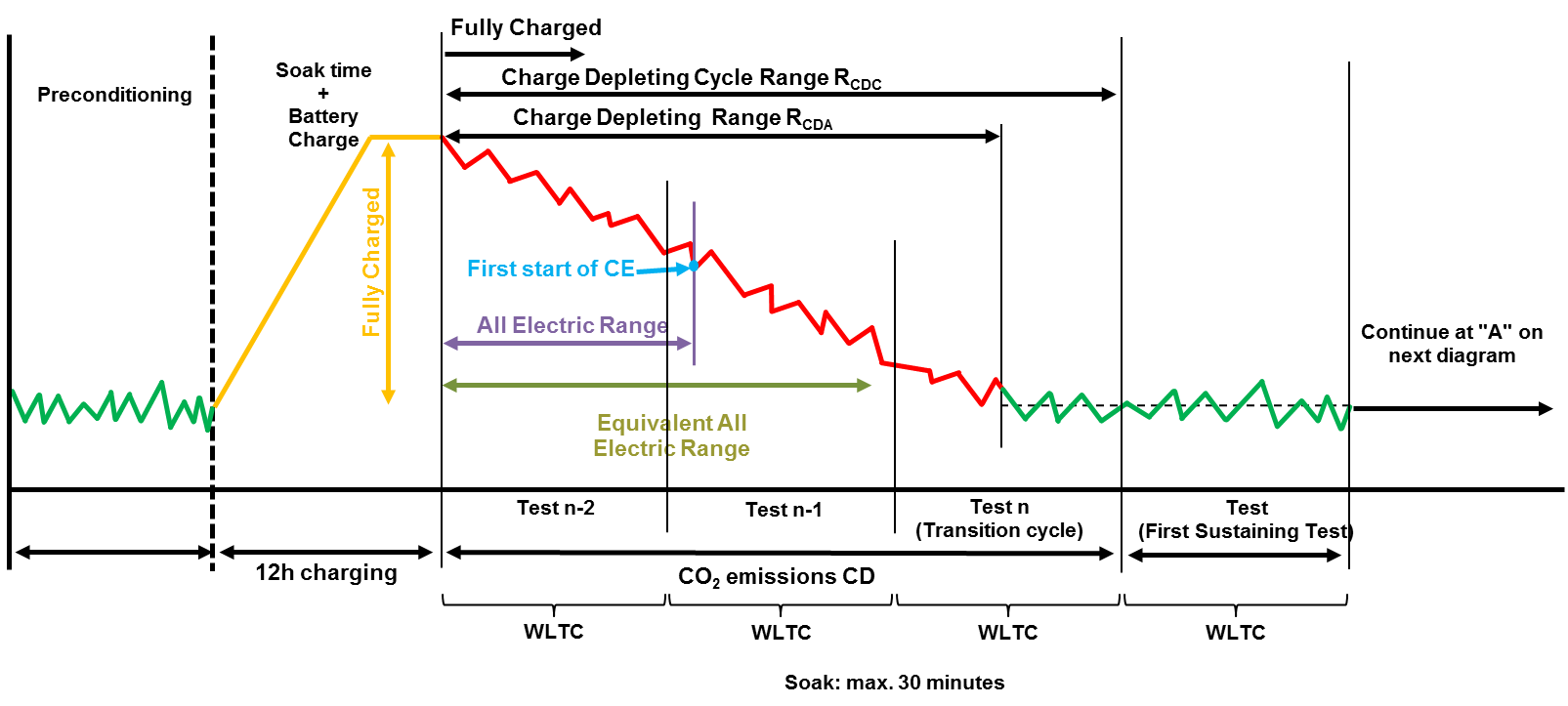
Annex 8 - Appendix 1a

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

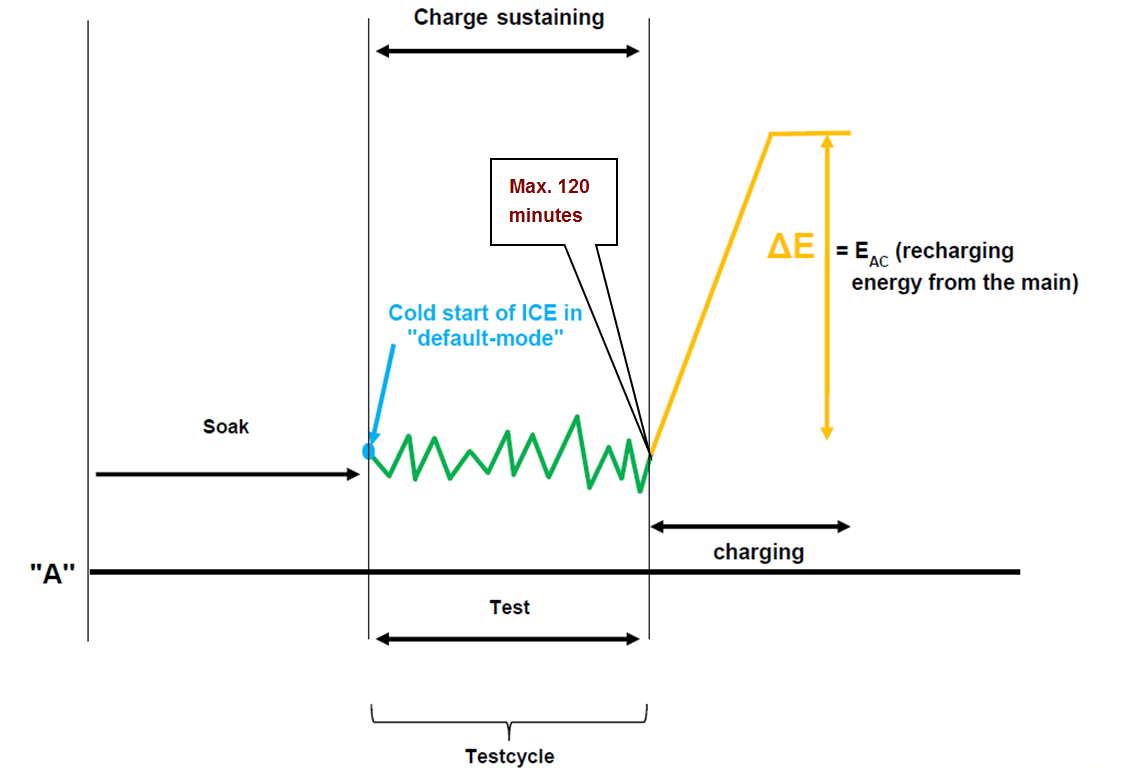
# **OVC-HEV, Charge-depleting Test**



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**



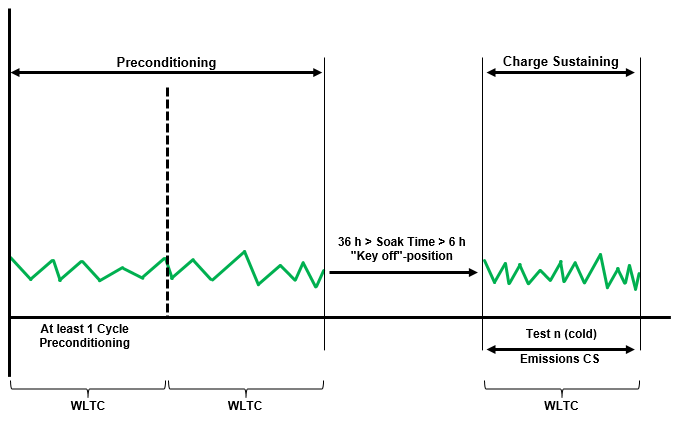
Annex 8 -Appendix 1b

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**



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 CO2 and fuel consumption measurement results when testing NOVC-HEV and OVC-HEV vehicles.

1.1. Separate CO2 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, , shall be defined as follows and might be supplied by the manufacturer :

2.1. The coefficient shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with and at least one with 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 .

2.1.1. coefficients for the individual phases as well as for the complete test cycle are defined as:

(1)

where:

are the fuel consumption correction coefficients, l/100 km/Wh/km;

are the fuel consumptions measured during the ith test, l/100 km;

are the electricity balances measured during the ith test, Wh/km;

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 ()

2.3.1. The fuel consumption at shall be determined by the following equation:

(2)

where:

is the fuel consumption at ∆EREESS = 0, l/100 km;

is the fuel consumption measured during the test, l/100 km;

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. CO2 emission correction coefficient, , shall be defined as follows and may be supplied by the manufacturer

3.1. The coefficient shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with and at least one with 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 .

3.1.1. The coefficient is defined as:

(3)

where:

is the CO2 emissions correction coefficient, g/km/Wh/km;

are the CO2 emissions measured during the ith test, g/km;

is the electricity balance during the ith test, Wh/km;

is the number of measurements.

3.1.2. The CO2 emission correction coefficient shall be rounded to four significant figures. The statistical significance of the CO2 emission correction coefficient is to be judged by the responsible authority.

3.1.3. The CO2 emission correction coefficient shall be determined for the CO2 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 CO2 emission correction coefficients for each individual WLTC phase may be developed.

3.1.4. CO2 emissions at zero REESS energy balance shall also be calculated for complete WLTC and corrected to zero.

3.2. CO2 emission at zero REESS energy balance (M0)

3.2.1. The CO2 emission M0 at shall be determined by the following equation:

(4)

where:

are the CO2 emissions at zero REESS energy balance, g/km;

is the CO2 emissions correction coefficient, g/km/Wh/km;

is the electricity balance measured during test, Wh/km.

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 and (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 REESS shall be recorded. The preconditioning shall be stopped at the end of the cycle when the break-off criterion is fulfilled according to paragraph 3.2.4.5. of this Annex.

2.1.4. Alternatively, at the request of the manufacturer, the state of charge of the REESS before preconditioning can be set according to the manufacturer’s recommendation in order to fulfill the break-off criterion.

In such a case, an additional ICE preconditioning procedure, such as that 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.

2.2. OVC-HEV combustion engine and REESS preconditioning when the test procedure starts with a 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 CS condition.

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 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 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

Utility factor (UF) for OVC-HEVs

1. Utility Factors are ratios based on driving statistics and the ranges achieved in CD mode and CS mode for OVC-HEVs and are used for weighting emissions, CO2 emissions and fuel consumptions.

2. Each Contracting Party may develop its own UFs.

3. Utility factors shall be calculated according to the following equation:

where:

cx are utility factor equation constants from Table A8.App.5;

x is the RCDC 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]

1. \* 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. [↑](#footnote-ref-2)