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Light vehicles – Global Technical Regulation No. 15 on Worldwide harmonized Light vehicles Test Procedure (WLTP)

Proposal for amendments to global technical regulation No. 15 on Worldwide harmonized Light vehicles Test Procedure (WLTP)Proposal for determination of system power of hybrid vehicles for use with the Worldwide harmonized Light vehicles Test Procedure (WLTP)

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Submitted by the Informal Working Group on Worldwide harmonized Light vehicles Test Procedure (WLTP)*

The text reproduced below was prepared by the Informal Working Group (IWG) on Worldwide harmonized Light vehicles Test Procedure (WLTP) in line with Phase 1B of its mandate (ECE/TRANS/WP.29/AC.3/39). A first draft of this proposal (GRPE-71-25 and GRPE-71-26) was introduced by the IWG on WLTP at the seventy-first session of GRPE (see report ECE/TRANS/WP.29/GRPE/71, paras. 14-16). The text is reproduced as a consolidated version.

[placeholder for any notes]

* In accordance with the programme of work of the Inland Transport Committee for 2014–2018 (ECE/TRANS/240, para. 105 and ECE/TRANS/2014/26, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

Draft proposal for determination of system power of hybrid vehicles

I. Statement of technical rationale and justification

A. Introduction

1. The WLTP test procedure requires information about the vehicle engine power rating to achieve certain purposes related to performing the test procedure. These purposes include classification of electrified vehicles into distinct Power-to-Mass ratio classes, based on the powertrain power rating; and application of the so-called "downscaling method" that enables the test reference cycles to be adapted for low powered vehicles, also based on the powertrain power rating.

2. For purposes of rating the motive power of light vehicles, the UNECE currently provides a regulation under the 1958 Agreement that can be used for approval of internal combustion engines (ICE) and pure electric drivetrains for M and N category vehicles. It focuses on the determination of engine power values and in many cases is sufficient to achieve the above purposes.

3. However, the technical description part of the regulation merely provides for the individual determination of the power of either an ICE or an electric motor. For vehicles with more than one power source, such as an engine and an electric motor that combine to provide a total combined system power, the regulation does not establish a method to determine this total power. The simple addition of individual power results from engine and electric motor is insufficient and can lead to incorrect estimations of the power performance of the vehicle. For example, in many cases (likely the majority), it is the propulsion battery system (also referred to as rechargeable electric energy storage system or REESS) and not the electric motor that limits and therefore determines the power of an electric powertrain. The specific way in which the control system combines the power of an engine and an electric motor (or multiple electric motors) under peak power demand can also affect the validity of simple addition. The situation may become worse in the future because more and more sophisticated hybrid vehicle concepts with distributed power sources are likely to gain market maturity (e.g. electrified vehicles with rim motor concepts, and all-wheel-drive configuration with separate drive motors powering each axle).

B. Procedural background and ~~future development of the WLTP~~relation to WLTP

4. Currently, a clear demand for an improved power determination procedure comes from the members of the WLTP IWG, as the Electrified Vehicles subgroup is in need of a total system power specification for the purposes of classification and downscaling. Members of the EVE IWG have also acknowledged that system power ratings are also useful for other purposes. Among others, it may serve as customer technical information, may be used by regulators (as basis for taxation programs) or by insurance providers (as a classifier for determining premiums).

5. Accordingly, Part B of the second EVE mandate includes a subtask to develop an amendment to gtr No. 15 to establish a procedure for determining the powertrain performance of electrified vehicles for use with the WLTP test procedure.

6. Given the above described situation and according to its mandate under the UNECE, the EVE IWG established a subgroup "Determining power of EVs." The goal was to clarify how an improved technical procedure for the determination of the system power of sophisticated powertrains, such as hybrid electric vehicles with multiple power sources, or pure electric vehicles with more than one electric motor, could be realized in an efficient and simple way.

7. The scope of the work covered light duty vehicles (passenger cars -M1 and light duty vehicles -N1) and aimed to develop a recommendation or regulation for determination of the performance criterion "system power." It was agreed that the procedure shall cover all types of HEV (ordinary –NOVC-HEVs and plug-in –OVC HEVs), including the following configurations: Series HEV, Parallel HEV, and Power split HEV. The procedure shall also cover PEVs with one or more than one electric motor for propulsion (e.g. rim motor concepts, or all-wheel drive configurations served by multiple drive motors). The system power rating, as a measure of vehicle performance, is intended to be comparable to the measure commonly used for conventional vehicles, i.e. the rated power of an ICE.

C. Background on driving cycles and test procedures considered

8. The EVE IWG recognized that activities with similar focus were currently being pursued by several standardization organizations. The EVE IWG was therefore able to consider several possible paths forward for which considerable research had already occurred. The Society of Automotive Engineers (SAE), the Korea Automobile Testing & Research Institute (KATRI), and the International Organization for Standardization (ISO) had all begun considering how the power of an electric or hybrid vehicle could be best measured. The EVE IWG received presentations from experts with these organizations and discussed the merits and drawbacks of some of the methods proposed by each.

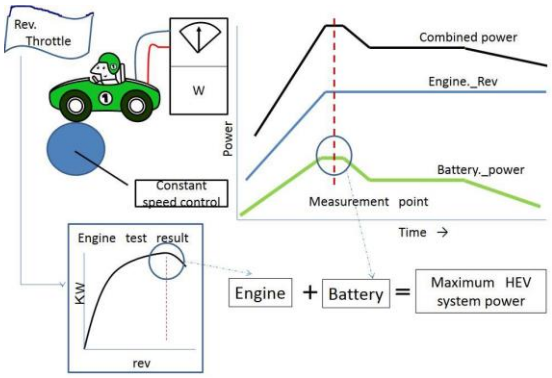
9. The SAE J2908 Task Force led by Argonne National Laboratory (ANL) started a project in November 2014. The project was initially scheduled to be finalized towards end of 2015. Three primary methods of determining HEV system power emerged from the research (referred to as Method 1, Method 2, and Method 3). The EVE IWG agreed with the characterization of these three primary methods as reasonable approaches to measure system power. The three methods vary in terms of how well the measure can be compared to traditional power determination for ICEs, and in terms of the ability to verify a reported value

10. Method 1 is the sum of estimated engine power (estimated by an applicable standard) and measured DC power from the battery. This method is fairly compatible with existing vehicle power ratings and fairly straightforward to verify. Method 2 is the sum of estimated shaft powers from the engine and the electric motors. This method provides the best compatibility with existing vehicle power ratings but imposes a higher burden of instrumentation to verify. Method 3 is the measured power at the axle or wheel. This method is easily verifiable by dynamometer testing, but because it measures only power at the wheels, it is not as comparable to existing vehicle power ratings.

11. KATRI started a research project in July 2013 with the aim of developing a national standard for the determination of a representative power for (N)OVC-HEVs and EVs with in-wheel motors. It is intended for use in the national vehicle classification. It was finalized in June 2015 and the result will be harmonized with the research result on determining power of EVs in EVE IWG. Nominal rating and system power tests were studied using a powertrain dyno or a chassis dyno with added instrumentation. Under KATRI, the definition of the hybrid system power follows the same approach as the SAE procedure, namely that it involves a simple addition of the rated engine power and the electric power of the battery (Hybrid system power = Engine power + Electric power). The engine power

is the rated power according UN-R85. The electric power is the measured power of the electric on board power source of the vehicle determined during chassis dyno testing. Aside from this procedure and similar to the SAE methodology, a somewhat more sophisticated system power test provides not only accurate measurement of wheel or axle power but also useful information of system torque.

12. The International Organization for Standardization (ISO) has also begun a project under New Work Item Proposal (NWIP) N3477 proposed by the Japan Automobile Research Institute (JARI), approved in June 2015. It started as a formal project of ISO/TC22/SC37/WG02. This ISO methodology also includes the definition of the hybrid system power as the arithmetic sum of engine power and battery power, as shown in previous cases (Hybrid system power = Engine power + Battery power). It is necessary to measure the battery output under the HEV system control. The engine power is the rated power determined by ISO 1585. The battery output should be measured when the hybrid system as a whole delivers maximum power on a chassis dyno. The exact point of maximum system power is determined by carrying out a series of test runs while driving the vehicle at different but constant speeds to find the maximum brake power of the chassis dyno that the vehicle is able to run against. The evaluation results in a power-versus-speed curve that shows a point of maximum power at a certain speed as shown in the following image.



13. During discussions among EVE members, Method 1 found the broadest acceptance since it showed to be quite similar to or the same as KATRI and ISO methodologies. The nominal rating Method 1 is based on determination of individual power at the component level (internal combustion engine, and battery power) and can therefore be considered as similar to current engine power ratings. ANL has investigated different test types (e.g. running a test vehicle at several fixed speeds vs. running a test vehicle with a speed sweep or ramp) in order to determine the maximum system power a vehicle can deliver.

14. Under Method 1, the definition of the hybrid system power follows a simple addition of the rated engine power and the electric power of the battery (Hybrid system power = Engine power + Electric power). The engine power is the rated power by SAE J1349. Electric power is a measured electric assist on the dynamometer.

15. At EVE-22, the contracting parties reached consensus that the ISO method presented the best option as a basis for development of a test procedure for system power determination. This method is very similar to the SAE Method 1. It shows good verifiability, and as a measure of vehicle performance it is comparable to ICE rated power, which makes comparisons between ICE ratings from conventional vehicles and maximum HEV system power ratings relatively straightforward.

16. The EVE IWG recognized that Method 3 is a sophisticated test, leading to highly verifiable results, e.g. for engineers to communicate power levels. However, Method 3 was not selected in part because, being based on a measurement of wheel or axle power rather than component power, it is not directly comparable to current measures of ICE vehicle power.

17. Similarly, Method 2 was not selected in part because it would pose a greater burden for verification due to the need for relatively complex and invasive instrumentation.

D. Technical feasibility, anticipated costs and benefits

18. The ISO method includes two variations (referred to informally as the German method and the Japan method). There was some debate as to whether the GTR should select a single method, or provide a choice between the two variations. It was generally decided that having two methods would be acceptable (as long as the results are the same given the correct inputs), because it provides the opportunity to choose the method that best fits the data or equipment that are available, or the powertrain architecture being tested.

19. In designing and validating the ISO method, strong emphasis has been put on its practicability. While the methods are believed at this time to deliver equivalent results, this remains to be investigated in more detail. It could be said that both methods include some uncertainty in that both methods call for certain information to be estimated or assumed. The German method relies on an estimated gear efficiency, while the Japan method requires an assumed electrical component efficiency. The EVE IWG recognized that it would be necessary to perform testing to validate the ability of the method to effectively serve the purposes of WLTP as envisioned.

20. It was also recognized that the state of charge (SOC) of the REESS could affect measured power. After technical discussions with experts from the WLTP –IWG Subgroup EV, the members of the EVE IWG agreed on the concept to determine the maximum HEV system power with REESS fully charged.

21. Another step to be taken is the validation of ISO test results, after review of the selected method(s). Several contracting parties volunteered to assist with such testing, including ECCC (Canada), Joint Research Centre (JRC), EPA, and possibly NTSEL.

22. At EVE 22, the co-chair from Japan requested that EVE leadership take on the task of drafting the GTR, with initial priority placed on the reference method over the candidate method. Accordingly, a drafting group was formed to draft this document.

23. It was also suggested that at some point in the near future, a parallel effort should also be undertaken to further develop the candidate method by means of testing at laboratories of the contracting parties, but at this time this is considered a secondary goal.

24. The specification of a test procedure for power determination will remove significant uncertainty that manufacturers now face in communicating the power level of electrified vehicles both to the public and to regulating authorities. Initially the adoption of the procedure may bear some costs for vehicle manufacturers, technical services and authorities, at least considered on a local scale, since some test equipment and procedures may 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.

II. Text of the global technical regulation

1. Purpose

This global technical regulation (gtr) aims at providing a worldwide harmonized method to determine a system power rating of electrified light-duty vehicles in a repeatable and reproducible manner and that is comparable to traditional measures of system power applicable to conventional vehicles. The results will provide a basis for consistent application of the classification and downscaling provisions of WLTP for the purpose of regional type approval and certification procedures.

2. Scope and application

This gtr applies to hybrid electric vehicles (HEV) classified as passenger cars or light-duty trucks, with an internal combustion engine (ICE) and one or more electric motors powered by one or more rechargeable electrical energy storage systems (REESS) used for propulsion.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

For the purposes of this document, the terms and definitions given in ISO 1585, ISO 23274 (all parts), ISO/TR 8713 and the following apply.

3.1. Definition 1Test equipment

[to be defined as necessary consistent with WLTP]

3.2. Definition 2Road load and dynamometer setting

[to be defined as necessary consistent with WLTP]

3.3. Definition 3Pure electric, hybrid electric and fuel cell vehicles

[to be defined as necessary consistent with WLTP]

3.4. Definition 4Powertrain

[to be defined as necessary consistent with WLTP]

3.5. Definition 5General

[to be defined as necessary consistent with WLTP]

3.6. Definition 6PM/PN

[to be defined as necessary consistent with WLTP]

3.7. Definition 7WLTC

[to be defined as necessary consistent with WLTP]

3.8. Definition 8Procedure

[to be defined as necessary consistent with WLTP]

4. Abbreviations

4.1. General abbreviations

[to be defined as necessary consistent with WLTP]

AWD All wheel drive

HEV hybrid-electric vehicle

ICE internal combustion engine

ICEV internal combustion engine vehicle

ISO International Organization for Standardization

REESS Rechargeable electrical energy storage system

SOC state of charge

UN United Nations

4.2. Chemical symbols and abbreviations

[to be defined as necessary consistent with WLTP]

5. General requirements

6. Performance requirements

7. Test conditions

7.1. Test instrumentation

7.1.1 Chassis dynamometer

The chassis dynamometer shall have the absorption capacity for the power of vehicle by fixed speed control.

7.1.2 Test room

Conditions of the test room shall be adjusted as follows:

The reference temperature 298K±10K (25°C±10 °C)

Test atmospheric conditions: Pd 80kPA < Pd < 110 kPa

7.1.3 Cooling fan

Fans shall be used to cool the vehicle to maintain the proper operating temperature. However, excessive cooling is prohibited. Air speed in front of the vehicle shall not be higher than the vehicle speed.

7.2 Measurement

7.2.1 Measurement item and accuracy

[insert Table 1 from ISO document]

Measurement devices shall be of certified accuracy traceable to an approved regional or international standard.

7.2.2 Measurement frequency

All the items in [[Table 1 of 5.2.1]], except barometric pressure and room temperature shall be measured and recorded at a frequency of not less than 10 Hz.

8. Test procedure

8.1 General

The purpose of the following test procedures is to determine the maximum system propulsion power of an HEV (maximum HEV system power) on a chassis dynamometer at fixed speeds. Two optionally, equitable test procedures, namely:

— a test procedure via measured RESS power and determined ICE power, consecutively named the test procedure option 1 (TP1), and

— a test procedure via torque and speed measurement, consecutively named the test procedure option 2 (TP2)

are applicable.

The following clauses provide the requirements for the test procedure execution towards preparation, test and calculation of the maximum HEV system power. Specific requirements towards TP1 and TP2 are mentioned in the following clauses, if necessary.

8.2 Preparation of chassis dynamometer

8.2.1 Roller

The chassis dynamometer roller(s) shall be clean, dry and free from foreign material which might cause tire slippage.

8.2.2 Tire slippage

Additional weight may be placed on or in the vehicle to eliminate tire slippage. The use of any additional weight shall be recorded.

8.2.3 Chassis dynamometer warm-up

The chassis dynamometer shall be warmed up in accordance with the dynamometer manufacturer's recommendations, or as appropriate.

8.2.4 Chassis dynamometer control

The chassis dynamometer shall be controlled in fixed speed mode for the power test. Only for the requirements towards vehicle conditioning (8.8.2), the chassis dynamometer shall be controlled in road load mode.

8.3 Preparation of vehicle

The tire pressure shall be adjusted in accordance with the vehicle manufacturer's recommendation or the owner's manual. The vehicle lubricants and levels specified by the manufacturer shall be used.

Fuel shall be in accordance with the vehicle manufacturer's recommendation or ISO 1585.

8.4 Preparation of measurement devices

The measurement devices shall be installed at suitable position(s) and warmed up as appropriate.

Specific for TP2: The gearbox output shaft(s) or the driven wheel(s) shall be prepared with appropriate, calibrated torque and rotational speed measurement device(s).

For a driven axle powered via differential and two wheels, it is sufficient to install only one torque and rotational speed measurement device at shaft/wheel. In this case, the measured torque at shaft/wheel shall be multiplied by factor 2 in order to get the sum of torque per driven axle.

Note: The torque and rotational speed measurement devices can be substituted by traction force and speed measured by the chassis dynamometer, if the accuracy of this measurement devices fulfill the same requirements as for the shaft/wheel measurement devices. If so, the measured values for traction force and speed have to be transformed by calculation to the required values for torque and rotational speed at shaft/wheel taken into account the specific data of the tires and the proportional vehicle weight at axle/wheel used during the test (e.g.: rolling friction losses, dynamic rolling radius).

[Continue copying text of ISO procedure at 6.5 and beyond ....]

Annex 10

Test procedure for determination of system power of hybrid and electric vehicles with more than one propulsion source

1. General requirements

1.1. The cycle to be driven depends on the test vehicle's rated power to mass in running order, W/kg, and its maximum velocity, v_{max}, and its mass, kg.

The cycle resulting from the requirements described in this annex shall be referred to in other parts of the GTR as the "applicable cycle".

2. Vehicle classifications

2.1. Class 1 vehicles have a power to mass in running order ratio $P_{mr} \leq 22$ W/kg.

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

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

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

3. Test cycles

3.1. Class 1 vehicles

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

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

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

3.2. Class 2 vehicles

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

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

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

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

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

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

3.3. Class 3 vehicles

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4. Duration of all phases

3.4.1. All low speed phases last 589 seconds.

3.4.2. All medium speed phases last 433 seconds.

3.4.3. All high speed phases last 455 seconds.

3.4.4. All extra high speed phases last 323 seconds.

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.

At the option of the Contracting Party, the WLTC city for Class 3a and 3b vehicles may be excluded.