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Inland Transport Committee

World Forum for Harmonization of Vehicle Regulations

Working Party on Pollution and Energy

Proposal for a new UN GTR on In-vehicle Battery Durability for Electrified Heavy Duty Vehicles

Submitted by the Informal Working Group on Electric Vehicles and the Environment (EVE)*

A first draft of the text for a new UN GTR on in-vehicle battery durability for heavy duty electrified vehicles is reproduced below. The text was prepared by the Informal Working Group (IWG) on Electric Vehicles and the Environment (EVE) following the authorization given by WP.29/AC.3 in November 2022 to develop this new UN GTR (ECE/TRANS/WP.29/AC.3/60). The text and structure is based on the equivalent GTR for light duty vehicles (GTR No. 22), modified accordingly to take account of the different context, issues and requirements associated with heavy duty vehicles.

This document reflects the latest state-of-play following the 75th Session of EVE IWG. Where the content is still subject to discussion/decision the relevant sections of text have been put in square brackets. In some cases strikethrough text has been used to denote text which has been proposed for deletion – but for which that decision remains outstanding.

* In accordance with the programme of work of the Inland Transport Committee for 2024 as outlined in proposed programme budget for 2024 (A/78/6 (Sect. 20), table 20.5), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

UN Global Technical Regulation on In-vehicle Battery Durability for Electrified Heavy Duty Vehicles

Contents

Commented [EP1]: To be updated at the end

I. Statement of technical rationale and justification

[Editorial Note: To be prepared and added prior to submitting Working Document to GRPE]

II. Text of the GTR

1. Purpose

This Global Technical Regulation provides worldwide harmonised methods to determine in-vehicle battery durability performance of Heavy Duty Pure Electric Vehicles (HD-PEVs) and Heavy Duty Off-Vehicle Charging Hybrid Electric Vehicles (HD-OVC-HEVs).

Minimum performance requirements on in-vehicle battery durability of Heavy Duty Pure Electric Vehicles (HD-PEVs) and Heavy Duty Off-Vehicle Charging Hybrid Electric Vehicles (HD-OVC-HEVs) are introduced in an optional annex.

2. Scope and application

This GTR applies to vehicles of categories 1–2 and 2, that have a technically permissible maximum laden mass exceeding 3,855 kg, that (a) are HD-PEV or HD-OVC-HEV vehicles, and (b) have an originally installed battery as defined in this GTR.

At the option of the Contracting Party, the minimum technically permissible maximum laden mass may be exceeding 3,500 kg for the relevant categories.

The Contracting Party shall make a decision about the applicability of this GTR to Small Volume Manufacturers and special purpose vehicles and special axle formulas for their jurisdiction.

Electrified vehicle category trailers and semitrailers are excluded from this GTR.

[3. Definitions

The following definitions shall apply in this Global Technical Regulation.

3.1. *"Battery"* means, in the context of this GTR, any assembly of rechargeable electrical energy storage systems (REESS) installed in an electrified vehicle and used mainly for traction purposes.

3.2. [*"Originally installed battery"* means the battery that is installed in the vehicle at the time of manufacture [and that is configured according to the manufacturer's design/certification], or if the vehicle is manufactured without an installed battery, the battery that is installed in the vehicle when it is first operated on the road.]

3.3. *"Usable Battery energy ($UBE_{discharge}$)"* means the energy supplied by the battery from the beginning of the test procedure used for certification until the applicable end of test criterion of the test procedure as defined in Annex 3 of this GTR.

3.4. *"Certified usable battery energy"* ($UBE_{certified}$) refers to the UBE that was determined during the certification of the vehicle, according to Annex 3 of this GTR.

3.5. *"Measured usable battery energy"* ($UBE_{measured}$) means the UBE determined at the present point in the lifetime of the vehicle by the test procedure used for certification, according to Annex 3 of this GTR.

3.6. "Odometer" means that part of the odometer equipment, which indicates to the driver the total distance recorded by the vehicle since its entry into service.

3.7. "Gross Vehicle Mass (GVM)" of a vehicle means the maximum mass of the fully laden solo vehicle, based on its construction and design performances, as declared by the manufacturer. This shall be less than or equal to the sum of the maximum axles' (group of axles) capacity.

3.8. "Gross Train Mass (GTM)" of a power driven vehicle means the technically permissible maximum mass of the laden vehicle combination, as declared by the manufacturer of the towing vehicle.

3.9. *"State of certified energy"* (SOCE) means the measured or on-board UBE performance at a specific point in its lifetime, expressed as a percentage of *the certified usable battery energy.*

3.10. *"Minimum Performance Requirement" (MPR) means the minimum durability* performance, in terms of SOCE at a specific point in the life of the vehicle, that constitutes compliance with the [optional] durability provisions of this GTR [that a Contracting Party may optionally elect to enforce].

3.11. *"Declared Performance Requirement"* (DPR) means an SOCE value declared by the manufacturer that is greater than that of the corresponding MPR and which then becomes the minimum durability performance that constitutes compliance of that manufacturer with the durability provisions of this GTR.

3.12. *"SOCE monitor"* means an apparatus installed in the vehicle that maintains an estimate of the state of certified energy by means of an algorithm operating on data collected from the vehicle systems.

3.13. *"On-board SOCE"* ($SOCE_{read}$) means an estimate of state of certified energy produced by an SOCE monitor.

3.14. *"Measured SOCE"* ($SOCE_{measured}$) means the state of certified energy as determined by the measured usable battery energy divided by the certified usable battery energy.

3.15. *"V2X"* means the use of the traction batteries to cover external power and energy demand, such as V2G (Vehicle-to-Grid) for grid stabilisation by utilising traction batteries, V2F (Vehicle-to-Facility) for utilising traction batteries as facility storage for local optimisation or emergency power sources in times of power failure, V2H (Vehicle-to-Home) for utilising traction batteries as residential storage for local optimisation or emergency power sources in times of power failure, and V2L (Vehicle-to-Load, only connected loads are supplied) for use in times of power failure and/or outdoor activity in normal times.

[3.16. "*PTO-~~operation~~*" means Power Take-Off, i.e., any ~~energy throughput~~operation during stand still or ~~motion~~ propulsion of the vehicle for operational purposes other than V2X or motion.

PTO-operation (see R49, rev.07: 2.1.56. without engine-reference): "Power take-off operation" means any energy output for the purposes of powering auxiliary.

Power take-off (PTO) means a secondary engine shaft (or equivalent) that provides substantial auxiliary power for purposes unrelated to vehicle propulsion or normal vehicle accessories such as air conditioning, power steering, and basic

Commented [EP2]: PTO definition may or may not be required. Linked to equation of virtual distance in paragraph 5.2. To consider if the definition is needed if second eq is selected

On the other hand, it could still be relevant in the future to have the PTO definition included

In addition, need to decide which definition for PTO to use.

electrical accessories. ~~A typical PTO uses a secondary shaft on the engine to transmit power to a hydraulic pump that powers auxiliary equipment, such as a boom on a bucket truck. You may ask us to consider other equivalent auxiliary power configurations (such as those with hybrid vehicles) as power take-off systems~~

Power take-off (PTO) means supplying power from the engine (ICE, motor) to operate auxiliaries equipment unrelated to vehicle traction or normal vehicle auxiliaries(24V/12V-DCDC), such as oil pumps, water pumps (for concrete mixers, garbage trucks, fire trucks etc.).

Electrical Power take-off (ePTO) means directly REESS that provides substantial auxiliary power for purposes unrelated to vehicle propulsion or normal vehicle accessories (heater, 24/12V-DCDC) such as air pump, oil pump, water pump (for Cargo Thermal Control trucks, refrigerator trucks, cabin heater and air-conditioning,…)]

[3.17. *"Total energy throughput during V2X and/or PTO and/*or non-traction purposes *"* means the total amount of energy in kWh discharged during V2X and/or PTO applications, which needs to be provided according to Annex 2.]

3.18. *"*Energy throughput" is the total amount of energy in kWh discharged from the REESS, which needs to be provided according to Annex 2.

[3.19. *"*Energy throughput counter*"* means the system including [eventual] hardware and software that records the amount of energy in kWh during all discharge events.]

3.20. *"Pure electric vehicle"* (PEV) means a vehicle equipped with a powertrain containing exclusively electric machines as propulsion energy converters and exclusively rechargeable electric energy storage systems as propulsion energy storage systems.

3.21. *"Off-vehicle charging hybrid electric vehicle"* (OVC-HEV) means a hybrid electric vehicle that can be charged from an external source.

]

4. Abbreviations

BMS	Battery Management System
[DoD	Depth of Discharge]
DPR	Declared Performance Requirement
[ePTO	Electrical Power Take-Off]
[FSD	Full Scale Deflection]
GTM	Gross Train Mass
GNSS	Global Navigation Satellite System
GVM	Gross Vehicle Mass
HD	Heavy Duty
HD-OVC-HEV	HD Off-Vehicle Charging Hybrid Electric Vehicle
HD-PEV	HD Pure Electric Vehicle
MPR	Minimum Performance Requirement
OTA	Over the Air
PTO	Power Take-Off
REESS	Rechargeable Electrical Energy Storage System

SOCE	State of Certified Energy
UBE	Usable Battery Energy
V2F	Vehicle to Facility
V2G	Vehicle to Grid
V2H	Vehicle to Home
V2L	Vehicle to Load
V2X	Vehicle to Grid, to Facility, to Home, to Load

5. Requirements

5.1. State-of Certified Energy (SOCE) monitor

The manufacturer shall install a SOCE monitor that operates during the life of the vehicle. The SOCE monitor shall maintain an estimate of the state of certified energy (on-board SOCE).

The manufacturer shall determine the algorithms by which on-board SOCE is determined for the vehicles they produce. The manufacturer shall update the on-board SOCE with sufficient frequency as to maintain the necessary degree of accuracy during all normal vehicle operation.

The on-board SOCE shall have a resolution of at least 1 part in 100 and be used for the purposes of verification as the nearest whole number from 0 to 100.

The manufacturer shall make available the most recently determined values of the on-board SOCE via the OBD port and optionally over-the-air (OTA).

For the purposes of consumer information, the manufacturer shall make easily available to the owner of the vehicle the most recently determined value of the SOCE monitor via at least one appropriate method. The resolution and method for the customer values shall be determined in agreement with the authorities. For example:

(a) dashboard indicator;

(b) infotainment system;

(c) remote access (such as via mobile-phone applications).

5.2. Battery Performance Requirements

The battery durability requirements of this GTR are defined in terms of Minimum Performance Requirements (MPR*i*), which represent minimum allowable values for SOCE at specific points in the lifetime of the vehicle. Vehicles falling under the categories of HD-OVC-HEVs and HD-PEVs shall meet the Minimum Performance Requirements [as reported in the tables of the optional Annex 4 if elected to be enforced by a Contracting Party]. [The MPRs may differ depending on the category of the vehicle and type of propulsion].

[In order to address regional considerations, a Contracting Party may optionally elect to enforce Minimum Performance Requirements (MPR*i*) from the tables of the optional Annex 4.]

[A SOCE monitor shall be installed on vehicles of categories 1–2 and 2 and their values monitored in view of future amendment of this GTR.]

A manufacturer may elect to declare a Declared Performance Requirement (DPR*i*) having an SOCE value that is higher than that of the corresponding MPR. The DPR*i* shall then replace the MPR*i* for the purposes of determining compliance by that manufacturer.

[The manufacturer shall ensure that batteries installed in vehicles comply with the rules specified in paragraph 6.4.2. for the MPR*i* (or DPR*i* if applicable), [if a Contracting Party elects to enforce Minimum Performance Requirements (MPR*i*) from the tables of the optional Annex 4.]]

[At the request of the manufacturer and for vehicles designed with V2X or not-traction purpose applications and PTO, the equivalent virtual distance calculated following the equation below will be reported by each vehicle.

If an energy throughput counter for V2X + PTO + not-traction purposes is available:

$$\textbf{\textit{Virtual distance}}\ (km) = \text{Odometer km} \times \left(\frac{\text{total energy throughput during V2X} + PTO + not - traction\ purpose\ [Wh]}{total\ propulsion\ energy\ [Wh]}\right)$$

otherwise,

$$\textbf{\textit{Virtual distance}}\ (km) = \text{Odometer km} \times \left(\frac{\text{total energy throughput } [Wh] - total\ propulsion\ energy\ [Wh]}{total\ propulsion\ energy\ [Wh]}\right)$$

referring to the total energy throughput calculated as the sum of the net propulsion energy and additional application discharge energy.

The total distance used for confirming the compliance with the minimum performance requirements when applicable will consist of the sum of the distance driven and the virtual distance. The total virtual distance shall be recorded and monitored.]

Commented [EP3]: EVE 74
Decision needed as to which equation to include.
Links to definition for PTO above and Part C verification (see paragraph 6.5.).

6. In-Use Verification

6.1. Definitions of Families

Vehicles having the same characteristics with respect to their evaluation under Part A or Part B below shall be grouped respectively into the Part A or Part B vehicle families for the purpose of compliance verification. Families under Part A shall have the same characteristics with respect to verification of the SOCE monitor. Families under Part B shall have the same characteristics with respect to verification of battery durability.

Families with the same characteristics with respect to compliance verification shall be defined as follows:

6.1.1. For Part A: Verification of the Monitor

Only vehicles that are substantially similar with respect to the following elements may be part of the same monitor family:

(a) Algorithm for estimating on-board SOCE;

(b) Sensor configuration (for sensors used in determination of SOCE estimates);

(c) Characteristics of battery cell which have a non-negligible influence on accuracy of monitor;

(d) Type of vehicle (HD-PEVs or HD-OVC-HEVs);

At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may deviate from the above criteria for families.

6.1.2. For Part B: Verification of Battery Durability

Only vehicles that are substantially similar with respect to the following elements may be part of the same battery durability family:

(a) Vehicle category;

(b) Type and number of electric machines, including net power, construction type (asynchronous/ synchronous, etc.), and any other characteristics having a non-negligible influence on battery durability;

(c) Type of battery (dimensions, type of cell, including format and chemistry, capacity (Ampere-hour), nominal voltage, nominal power;

(d) Battery management system (BMS) (with regards to battery durability monitoring and estimations);

(e) Passive and active thermal management of the battery;

(f) Type of electric energy converter between the electric machine and battery, between the recharge-plug-in and battery, and any other characteristics having a non-negligible influence on battery durability;

(g) Operation strategy of all components influencing the battery durability.

At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may deviate from the above criteria for families.

[6.1.3. For Part C: Verification of reported virtual distance

Only vehicles that are substantially similar with respect to the following elements may be part of the same [virtual distance] family:

(a) Algorithm for reported virtual distance;

(b) Sensor configuration (for sensors used in determination of virtual distance);

(c) Characteristics of battery cell which have a non-negligible influence on accuracy of monitor;

(d) Type of vehicle (HD-PEVs or HD-OVC-HEVs).

At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may deviate from the above criteria for families.]

6.2. Information gathering

The following information shall be made available to the authorities by the manufacturer in a format to be agreed between the authorities and the manufacturer: annual report on relevant warranty claims; and annual statistics on repairs for both batteries and other systems that might influence the electric energy consumption of the vehicle. Such information shall be made available once a year for each battery durability family for the duration of the period defined in the optional Annex 4 after the last vehicle of this family is sold.

6.3. Part A: Verification of SOCE monitor

6.3.1. Frequency of verifications

The manufacturer shall complete the procedure for in-use verification for Part A with a frequency agreed with the regional authorities, as defined in the Annex 4 after the last vehicle of each monitor family is sold and report the results of the verification to the authorities. The authorities may decide to proceed with their own verification of Part A, at a frequency and magnitude based on risk assessment, or request more information from the manufacturers. With the agreement of all Contracting Parties involved, the verification of Part A for vehicles in the same monitor family may be combined between different Contracting Parties. In such cases the relevant Contracting Parties shall be considered as a single authority for the purposes of this verification.

[At the option of the Contracting Party, a minimum annual sales volume for a monitor family may be defined, below which verification of monitors is not required]. Such families may still be selected to be tested for Part A, at the request of the responsible authorities.

6.3.2. Verification procedure

In order to verify the SOCE monitor, the value for the usable battery energy shall be measured at the time of the verification and the related value from the monitor shall be collected before the verification test procedure. To support future improvement of the GTR, indicator values shall be collected again after the verification test procedure. Those indicators read after the verification test procedure shall not be considered in the Part A verification.

The measured SOCE value shall be determined by dividing the measured value for the usable battery energy by the certified value for the usable battery energy, in accordance with the procedures defined in Annex 3 of this GTR, respectively, expressed in per cent.

$$SOCE_{measured} = \frac{UBE_{measured}}{UBE_{certified}} * 100$$

In cases where $UBE_{measured}$ is higher than the $UBE_{certified}$, the $SOCE_{measured}$ shall be set to 100 per cent.

[The different test procedures for the UBE determination are defined in Annex 3:

Method 1a: battery discharge by driving on a test track with characteristic regional speeds (paragraph 2.1. of Annex 3),

Method 1b: battery discharge by driving on the road ~~with average speed~~ (paragraph 2.2. of Annex 3)

Method 2: battery discharge by a bidirectional power supply system (paragraph 2.3. of Annex 3).

Alternative method: constant and transient cycles test method using a HD chassis dynamometer (paragraph 2.4. of Annex 3).]

6.3.3. Statistical Method for Pass/Fail decision for a sample of vehicles

An adequate number of vehicles (at least 3 and not more than 16) shall be selected from the same monitor family for testing following a vehicle survey (see Annex 1) which contains information designed to ensure that the vehicle has been properly used and maintained according to the specifications of the manufacturer. The following statistics shall be used to take a decision on the accuracy of the monitor.

For evaluating the SOCE monitor normalised values shall be calculated:

$$x_i = SOCE_{read,i} - SOCE_{measured,i}$$

Where

$SOCE_{read,i}$ is the on-board SOCE read from the vehicle *i* ; and

$SOCE_{measured,i}$ is the measured SOCE of the vehicle *i*.

For the total number of *N* tests and the normalised values of the tested vehicles, $x_1, x_2, \ldots x_N$, the average X_{tests} and the standard deviation *s* shall be determined:

$$X_{tests} = \frac{(x_1 + x_2 + x_3 + \cdots + x_N)}{N}$$

and

$$s = \sqrt{\frac{(x_1 - X_{tests})^2 + (x_2 - X_{tests})^2 + \ldots + (x_N - X_{tests})^2}{N - 1}}$$

For each N tests $3 \leq N \leq 16$, one of the three following decisions can be reached, where the factor A shall be set at 5:

(a) Pass the family if $X_{tests} \leq A - \left(t_{P1,N} + t_{P2,N}\right) \cdot s$

(b) Fail the family if $X_{tests} > A + \left(t_{F1,N} - t_{F2}\right) \cdot s$

(c) Take another measurement if:

$$A - \left(t_{P1,N} + t_{P2,N}\right) \cdot s < X_{tests} \leq A + \left(t_{F1,N} - t_{F2}\right) \cdot s$$

where the parameters $t_{P1,N}$, $t_{P2,N}$, $t_{F1,N}$, and t_{F2} are taken from Table 3.

Table 3
Pass/fail decision criteria for the sample size

	PASS		*FAIL*	
Tests (N)	$t_{P1,N}$	$t_{P2,N}$	$t_{F1,N}$	t_{F2}
3	1.686	0.438	1.686	0.438
4	1.125	0.425	1.177	0.438
5	0.850	0.401	0.953	0.438
6	0.673	0.370	0.823	0.438
7	0.544	0.335	0.734	0.438
8	0.443	0.299	0.670	0.438
9	0.361	0.263	0.620	0.438
10	0.292	0.226	0.580	0.438
11	0.232	0.190	0.546	0.438
12	0.178	0.153	0.518	0.438
13	0.129	0.116	0.494	0.438
14	0.083	0.078	0.473	0.438
15	0.040	0.038	0.455	0.438
16	0.000	0.000	0.438	0.438

6.3.4. Corrective measures for the SOCE monitor

A fail decision for the sample means that the monitor fails to report accurately the durability of the system and appropriate action shall be taken by the manufacturer with the agreement of the responsible authority. This may lead to the requirement that the manufacturer repairs or replaces the faulty monitor including the relevant sensors or applies software measures in all affected vehicles in the monitor family.

A pass decision or correction of the non-compliance is required for proceeding with Part B.

6.4. Part B: Verification of Battery Durability

6.4.1. Frequency of verifications

Data shall be collected yearly by the responsible authorities from a statistically adequate sample of vehicles within the same battery durability family selected randomly from a variety of climate conditions. The decision on the number of vehicles in the sample may be taken by the responsible

authority based on risk assessment methodology, but in principle should not be less than 500.

If the number of vehicles in the sample is less than 500, then on the request of the manufacturer and with the agreement of the responsible authority, a maximum of 5 per cent of the values may be excluded from the sample. In such a case, the manufacturer shall provide adequate information on the reason behind the exclusion for each vehicle to the authority.

If the number of vehicles in the sample is equal to or more than 500, then all vehicles shall be included in the sample. The data read shall be those of the SOCE monitor (and other relevant data, such as those defined in Annex 2).

6.4.2. Pass/Fail Criteria for the battery durability family[, if applicable]

A battery durability family shall pass if equal to or more than 90 per cent of monitor values read from the vehicle sample are above the MPR*i* or DPR*i*.

A battery durability family shall fail if less than 90 per cent of monitor values read from the vehicle sample are above the MPR*i* or DPR*i*.

6.4.3. Corrective Measures for the Battery Durability Family

In case of a fail for a battery durability family, corrective measures shall be taken with the agreement of the responsible authority in order to bring the family or part of the family affected by the issue into compliance.

[6.5. Part C: Verification of reported virtual distance or Energy throughput counter

6.5.1. Verification procedure

A verification of the reported virtual distance/energy throughput counter is only required if the manufacturer is requesting to apply the equivalent virtual distance/energy throughput option. In order to verify the virtual distance/energy throughput read from the vehicle, a test shall be performed with adequate and representative use of the vehicle in V2X or non-traction purposes and PTO, if applicable, to verify whether the increase in virtual distance reported is accurate. The total discharge energy during this use or alternatively the total discharge energy of the vehicle (defined as the sum of the discharge energy while driving and while using the V2X, not-traction purpose and PTO) shall be measured in order to calculate the measured virtual distance. The verification procedure use case (including the minimum amount of discharged energy corresponding to at least 50 km virtual distance) shall be agreed and approved by the responsible authority. If 50 km virtual distance cannot be reached with a fully charged battery, virtual distance required for verification shall be set to a value recommended by the manufacturer.

The following steps shall be performed to determine the necessary verification results. Table 4a refers to virtual distance verification, while Table 4b to Energy-throughout counter verification

Table 4a virtual distance verification

Step nr.	Input	Description	Output
Step 1	n.a.	Read the initial virtual distance or the total km (driving + virtual distance), total discharge energy while driving and the odometer according to Annex 2	$d_{virt,on\text{-}board,init}$ [km] $E_{drive,init}$ [kWh] $Odometer_{init}$ [km] or $E_{(driving+V2X,PTO..),init}$ [kWh]

			$d_{virt,on\text{-}board,init}$ [km] = total distance - odometers
Step 2	n.a.	Perform the V2X, non-traction purposes, PTO -use case and measure the discharged energy or alternatively the total discharge energy	$E_{V2X,PTO..,meas}$ [kWh] or $E_{(driving+V2X,PTO..),meas}$ [kWh]
Step 3	n.a.	Read the final virtual distance according to Annex 2 or (the total distance – odometer km)	$d_{virt,on\text{-}board,final}$ [km]
Step 4	From Step 1: $d_{virt,on\text{-}board,init}$ [km] $E_{drive,init}$ [kWh] $Odometer_{,init}$ [km] or $E_{(driving+V2X,PTO..),init}$ [kWh] From Step 2: $E_{V2X,PTO,..meas}$ [kWh] From Step 3: $d_{virt,on\text{-}board,final}$ [km]	Calculate the delta of on-board virtual distance: $\Delta d_{virt,onboard} = d_{virt,onb,final} - d_{virt,onb,init}$ Calculate the measured virtual distance: $\Delta d_{virt,meas} = Odometer$ [km] $\times \left(\frac{E_{V2X,PTO..meas}[kWh] - E_{V2X,PTO..init}[kWh]}{E_{drive,init}\ [\text{kWh}]}\right)$ or $\Delta d_{total,meas} = Odometer$ [km] $\times \left(\frac{E_{(driving+V2X,PTO..)meas}[kWh] - E_{(driving+V2X,PTO..)..init}[k}{E_{drive,init}\ [\text{kWh}]}\right.$	$\Delta d_{virt,on\text{-}board}$ [km] $\Delta d_{virt,meas}$ [km]

[Table 4b Energy-throughout counter verification

Table to be added]

6.5.2. Pass or fail of reported virtual distance

An agreed verification procedure use case (as mentioned in paragraph 6.5.1) shall be performed with an adequate number of vehicles (at least 1 and not more than 4) used in V2X, non-traction purposes or PTO. The verification of the reported virtual distance shall lead to a fail in the verification procedure if the reported delta virtual distance $_{\Delta dvirt,on\text{-}board}$ according to Table 4 is more than 5 per cent higher than the measured virtual distance $\Delta d_{virt,meas}$ according to Table 4. The following statistics shall be used to take a decision on the accuracy of the virtual distance.

For the purposes of deciding on a pass/fail result for the sample, 'p' is the count of passed results, and 'f' is the count of failed results. Each passed test result shall increase the 'p' count by 1 and each failed test result shall increase the 'f' count by 1 for the relevant open statistical procedure.

Upon the incorporation of valid V2X or PTO energy test results to an open instance of the statistical procedure, the responsible authority shall perform the following actions:

(a) update the cumulative sample size 'n' for that instance to reflect the total number of valid tests incorporated to the statistical procedure;

(b) following an evaluation of the results, update the count of passed results 'p' and the count of failed results 'f';

(c) check whether a decision is reached with the procedure described below.

The decision depends on the cumulative sample size 'n', the passed and failed result counts 'p' and 'f'. For the decision on a pass/fail of a verification sample the responsible authority shall use the decision chart in Table 5. The chart indicates the decision to be taken for a given cumulative sample size 'n' and failed count result 'f'.

Two decisions are possible for a statistical procedure for a given vehicle family:

(a) 'Sample pass' outcome shall be reached when the decision chart from Table 5 gives a "PASS" outcome for the current cumulative sample size 'n' and the count of failed results 'f'.

(b) 'Sample fail' decision shall be reached when, for a given cumulative sample size 'n', when the applicable decision chart from Table 5 gives a "FAIL" decision for the current cumulative sample size 'n' and the count of failed results 'f'.

If no decision is reached, the statistical procedure shall remain open and further results shall be incorporated into it until a decision is reached.

Table 5

Decision chart for Part C pass/fail verification

Failed result count f					
	3			FAIL	FAIL
	2		UND	UND	PASS
	1	UND	PASS	PASS	PASS
	0	PASS	PASS	PASS	PASS
n		1	2	3	4

[Note: 'UND' means undecided]

6.5.3. Corrective measures for reported virtual distance

A fail decision for the sample means that the virtual distance calculators (algorithm) fail to report accurately the virtual distance of the system and appropriate action shall be taken by the manufacturer with the agreement of the responsible authority. This may lead to the requirement that the manufacturer repairs or replaces the faulty virtual distance calculator in all affected and future vehicles in the battery durability family, to correct already reported virtual distances for this family and to repeat the procedure for verification of Part C in order to confirm the pass or fail.

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6.6. Process flow charts for Part A and Part B

The flow charts below illustrate the various steps in the verification process of Part A (Figure 1) and Part B (Figure 2).

Figure 1
Flow chart for Part A: Verification of Monitors

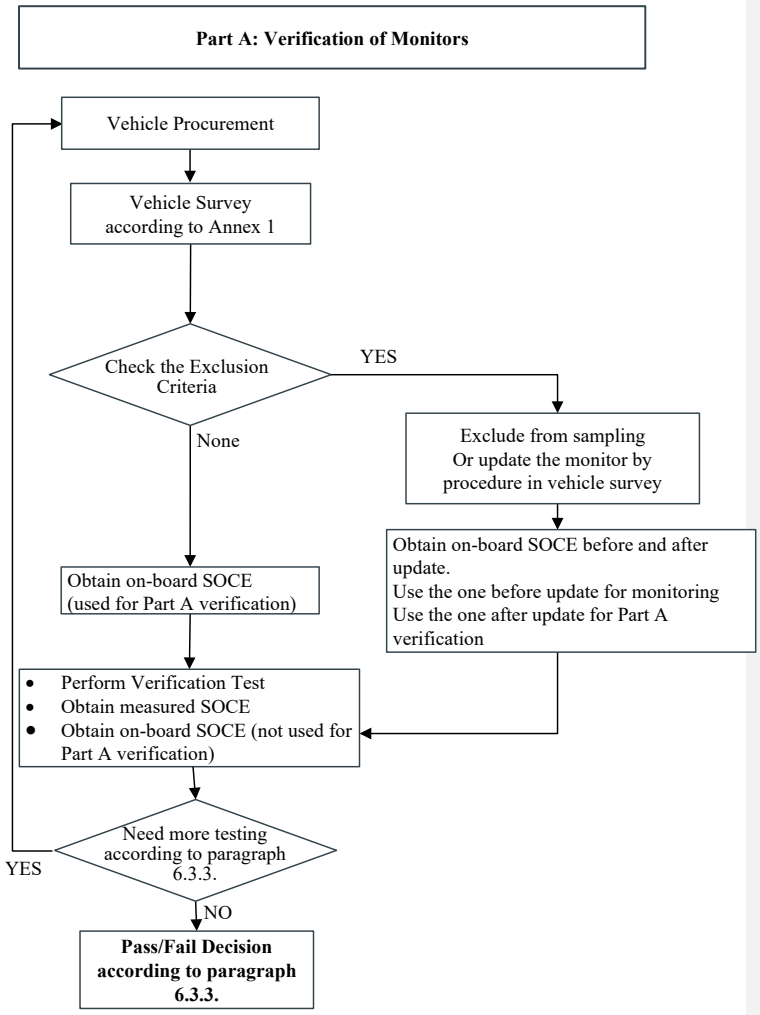
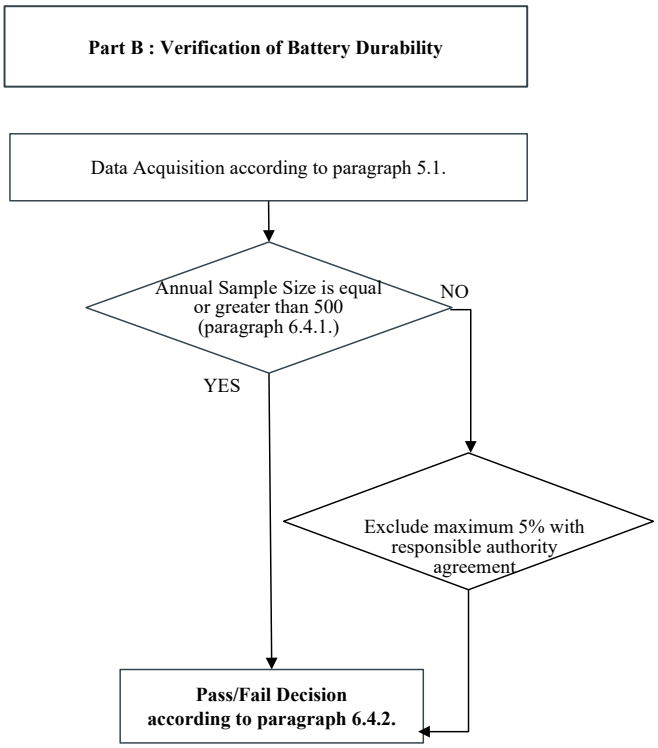


Figure 2
Flow chart for Part B : Verification of Battery Durability



7. Rounding

7.1. When the digit immediately to the right of the last place to be retained is less than 5, that last digit retained shall remain unchanged.

Example:

If a result is 1.2344 kWh but only three places of decimal are to be retained, the final result shall be 1.234 kWh.

7.2. When the digit immediately to the right of the last place to be retained is greater than or equal to 5, that last digit retained shall be increased by 1.

Example:

If a result is 1.2346 kWh but only three places of decimal are to be retained, and because 6 is greater than 5, the final result shall be 1.235 kWh.

Annex 1

Vehicle Survey

The vehicle survey shall be used for all vehicles selected for testing in Part A verification of SOCE monitor, for all the test methods, i.e., Method 1a, Method 1b, Method 2 and Alternative Method of Annex 3. Vehicles that fall under one of the exclusion criteria below shall be eliminated from testing, or otherwise updated according to the procedures described below.

	x = Exclusion Criteria	**x = Checked and reported**	**Confidential**
Date:			**x**
Name of investigator:			**x**
Location of test:			**x**
Country of registration:		**x**	

Vehicle Characteristics	**x = Exclusion Criteria**	**x = Checked and reported**	**Confidential**
Registration plate number:		**x**	**x**
*The vehicle must have **age and distance** travelled (defined as the time elapsed after manufacture) below the one required in the optional Annex 4 for the MPR verification*	**x**		
Is the vehicle either HD-PEV or HD-OVC-HEV? If no: the vehicle cannot be selected	**x**		
Date of manufacture:		**x**	

VIN:		**x**	
Emission class and character or Model Year		**x**	
Country of registration: *The vehicle must be registered in a Contracting Party*	**x**	**x**	
Model:		**x**	
Engine code:		**x**	
Engine volume (l):		**x**	
Engine power (kW):		**x**	
Electric Engine code:		**x**	
Electric Engine power (kW):		**x**	
Electric powertrain type		**x**	
Energy capacity and type of battery		**x**	
Gearbox type (auto/manual):		**x**	
Drive axle (FWD/AWD/RWD):		**x**	
Tyre size (front and rear if different):		**x**	
[Average fuel consumption for HD-OVC-HEVs]		**x**	

Is the vehicle involved in a recall or service campaign? **If yes: Which one? Have the campaign repairs already been done?** *The repairs must have been done before selecting the vehicle.*	**x**	**x**	

Vehicle Owner Interview
(the owner will only be asked the main questions and shall have no knowledge of the implications of the replies)

Name of the owner (only available to the accredited inspection body or laboratory/technical service)			x
Contact (address / telephone) (only available to the accredited inspection body or laboratory/technical service)			x

How many owners did the vehicle have?		**x**	
Did the odometer work? *If no, the vehicle cannot be selected.*	**x**		
Was the vehicle used for one of the following?			
As vehicle used in show-rooms?		**x**	
For racing / motor sports?	**x**		
Usage not originally prescribed		**x**	
Has the vehicle carried heavy loads over the specifications of the manufacturer? *If yes, the vehicle cannot be selected.*	**x**		
Have there been major engine, electric motor or vehicle repairs?		**x**	
Have there been unauthorised major engine or vehicle repairs? *If yes, the vehicle cannot be selected.*	**x**		
Was the propulsion battery changed or repaired? *If yes, the vehicle cannot be selected for testing, but information should be collected*	**x**	**x**	
Has there been an unauthorised power increase/tuning? *If yes, the vehicle cannot be selected.*	**x**		
Was any part of the emissions after-treatment system modified? *If yes, the vehicle cannot be selected*	**x**		
Where do you use your vehicle more often?	-	-	-
% motorway	-	**x**	-
% rural	-	**x**	-
% urban	-	**x**	-
Has the vehicle been maintained and used in accordance with the manufacturer's instructions? *If not, the vehicle cannot be selected.*	**x**		
Full service and repair history including any re-works *If the full documentation cannot be provided, the vehicle cannot be selected.*	**x**		
Battery related checks:			
How often did you charge the vehicle when:			
% with battery almost at 0 charge	**-**	**x**	
% with battery half charged	**-**	**x**	
% with battery almost fully charged	**-**	**x**	

On average how often were fast or ultra-fast*or MegaWatt chargers used in a month?** **What is your estimation of the percentage of time that the vehicle was used in the following ambient temperature ranges:** **Below -7C:** **Between -7C and 35C:** **More than 35C:**		**x** **x** **x** **x**	
Is the vehicle equipped with dynamic charging technology, such as, wireless power transfer, ground-rail, overhead trolley, or with overhead pantograph? **If available, on average how often was a dynamic charging technology, such as, wireless power transfer, ground-rail, overhead trolley, overhead pantograph, used to charge the vehicle in a month?**		**x** **x**	

* Ultra-fast charger: up to 600kW (ISO 15118, IEC61851...)
** MegaWatt Charging system: up to 3.75MW (ISO 15118, IEC 62196, …)

Vehicle Examination and Maintenance by the Testing Centre (please use the relevant entries according to the type of vehicle)	**x= Exclusion Criteria**	**x=checked and reported**	**Relevant for BEV**
Was the vehicle not charged adequately* for the last month? *If the vehicle was not charged adequately for the last month (as evidenced by values read from the vehicle under [point 7], Annex 2) and the tester wishes to use it for testing, then it has to be conditioned by operating the vehicle in a manner that results in discharge of at least 50 per cent of the usable capacity of the battery, followed by a full recharge.* Note: * Adequately in this sense means that the vehicle was not charged in a manner that would lead to an accurate SOCE	**x**		
Fuel tank level (full / empty) Is the fuel reserve light ON? *If yes, refuel before test.*		**x**	
Are there any warning lights on the instrument panel activated indicating a vehicle or exhaust after-treatment system malfunctioning that cannot be resolved by normal maintenance? (Malfunction Indication Light, Engine Service Light, etc?) *If yes, the vehicle cannot be selected*	**x**		
Is the SCR light on after engine-on? *If yes, the reagent should be filled, or the repair executed before the vehicle is used for testing.*	**x**		
Visual inspection exhaust system Check leaks between exhaust manifold and end of tailpipe. Check and document (with photos) *If there is damage or leaks, the vehicle cannot be tested*	**x**		
Exhaust gas relevant components Check and document (with photos) all emissions relevant components for damage. *If there is damage, the vehicle cannot be tested*	**x**		
Air filter and oil filter Check for contamination and damage. Change if damaged or heavily contaminated or less than 800 km before the next recommended change.		**x**	
Wheels (front & rear) Check whether the wheels are freely moveable or blocked or impeded by the brake.	**x**		**Y**

If not freely moveable, the vehicle cannot be selected.			
Drive belts & cooler cover *In case of damage, the vehicle cannot be tested.*	**x**		
Check fluid levels Check the max. and min. levels (engine oil, cooling liquid) / top up if below minimum		**x**	
Vacuum hoses and electrical wiring Check all for integrity. *In case of damage, the vehicle cannot be tested.*	**x**		**Y**
Injection valves / cabling Check all cables and fuel lines. *In case of damage, the vehicle cannot be tested.*	**x**		**Y**
Ignition cable (gasoline) Check spark plugs, cables, etc. In case of damage, replace them.		**x**	
EGR & Catalyst, Particle Filter Check all cables, wires and sensors. *In case of tampering or damage, the vehicle cannot be selected.*	**x**		
Safety condition Check tyres, vehicle's body, electrical and braking system status are in safe conditions for the test and respect road traffic rules. *If not, the vehicle cannot be selected.*	**x**		**Y**
Semi-trailer Are there electric cables for semi-trailer connection, where required?		**x**	**Y**
Check if less than 800 km away from next scheduled service, if yes, then perform the service.		**x**	**Y**
Powertrain Control Module calibration part number and checksum		**x**	**Y**
OBD diagnosis (before or after the range test) Read Diagnostic Trouble Codes & Print error log		**x**	
OBD Service Mode 09 Query (before or after the range test) Read Service Mode 09. Record the information.		**x**	
OBD mode 7 (before or after the range test) Read Service Mode 07. Record the information			

Remarks for: Repair / replacement of components / part numbers

Annex 2

[Values to be read from vehicles:

Commented [JRC4]: Further discussion/decision required

1. On board SOCE value (in %)
2. Odometer (i.e., distance driven by the vehicle) (in km)
3. Date of manufacture of the vehicle
4. Elapsed time since last charged by more than 50 per cent state of charge swing [Days]
5. Average battery temperature while propulsion system is active, during charging and (if equipped) during non-usage of the vehicles (i.e. non-propulsion system active, non-charging)

~~Maximum, minimum, average ambient temperature* the vehicle was exposed to during its lifetime~~

6. Total distance (sum of the distance driven as reported by the odometer and the virtual distance) [km], if applicable
7. Virtual distance (in km), if applicable
8. Total energy throughput in V2X and/or PTO and/or non-traction purposes [kWh], if applicable
9. Energy throughput, [kWh]

~~10. Capacity throughput~~

~~13. Total time of use of the battery~~

10. Total discharge energy while driving (propulsion system) [kWh], if available

~~*Note:* * ambient temperature to be read as daily averages~~

]

Annex 3

Test procedures for the UBE determination and performance parameters

1. General

For the calculation of the $SOCE_{measured}$, according to paragraph 6.3.2. of this GTR, the measured and certified values of usable battery energy (UBE) for HD-PEVs and HD-OVC-HEVs are required:

- $UBE_{measured}$ and $UBE_{certified}$

This annex describes the procedures for determining these parameters, in paragraph 2. and gives guidance on which measurements need to be performed on a vehicle selected in the Part A verification procedure.

1.1. Vehicle selection

1.1.1 Vehicle selection during certification

[The selection of the vehicle configuration during certification to verify the SOCE monitor shall be a vehicle corresponding to the lowest energy demand configuration within Part B family.]

1.1.2 Vehicle selection during Part A verification

[The vehicle selected during Part A verification shall be randomly selected. In the case in which the number of tests is less than the number of the Part B family, then "more than one vehicle selection is not allowed from the same Part B family". In the case in which the number of tests is equal to or greater than the number of the Part B families, then "at least one vehicle shall be selected from each Part B family ".]

1.2. Measurement requirements

Measurement devices shall be of certified accuracy as shown in Table A3/1 traceable to an approved regional or international standard.

All the items in Table A3/1 of paragraph 1.2 of this annex, unless specified otherwise in the table, shall be measured and recorded at a frequency equal to 20 Hz.

The items ‘atmospheric pressure’ and ‘room/ambient temperature’ shall be at least recorded as single measurement activity at start of the vehicle battery testing and after end of the vehicle battery testing in all the test procedures as described in paragraph 3. of this annex.

[Table A3/1
Measurement items and required accuracy

Item	*Units*	*Accuracy*	*Remarks*
Electrical voltage	V	±0.3 % FSD or ±1 % of reading	Whichever is greater. Resolution 0.1 V.
Electrical current	A	±0.3 % FSD or ±1 % of reading	Whichever is greater. Resolution 0.1 A

Item	*Units*	*Accuracy*	*Remarks*
Room/ambient temperature	K	±1 °C, with a measurement frequency of at least 0.033 Hz	
Time	s	± 10 ms; min. precision and resolution: 10 ms	
Vehicle speed	km/h	The total trip distance shall deviate by no more than 4 % from the reference distance	GNSS or Sensor or ECU

]

2. Test procedures

[Table A3/2 summarises the different test procedures for the UBE determination: Method 1a, Method 1b and Method 2.

The test method by using HD chassis dynamometer is an alternative method.]

[The same test method must be applied at certification to the SOCE monitor family concerned and during in-service testing Part A verification, if applicable and [in accordance] to regional [provisions, unless there is an agreement between the regional authority and the manufacturer].]

Table A3/2

Testing methods for UBE determination

Testing methods for UBE determination			
	HDV with no bidirectional charging system		**HDV with bidirectional power supply system**
	Method 1a	**Method 1b**	**Method 2**
Description	Discharge by driving on a test track with characteristic regional speeds with tolerances And charge	Discharge by driving on the road with average speed with higher tolerances And charge	Discharging and charging by a bidirectional power supply or charging station
Alternative Method	HDV Dyno testing with similar driving characteristics		

2.1. Method 1a: Discharge by driving on a test track with characteristic regional speeds

2.1.1. General test requirements

In Method 1a the battery shall be depleted by driving the vehicle on test track as specified in this paragraph at standard constant average speeds with a tolerance as specified in paragraph 2.1.2.7.

The manufacturer shall guarantee that all the traction batteries installed on the vehicle are engaged during the test to determine the Usable Battery Energy (UBE) certified and measured.

[The test track road surface shall be clean, dry, and its texture and composition shall be representative of current urban and highway road surfaces, ~~i.e. no airstrip-specific surface~~ according to regional regulations.]

Commented [75EVE-RG5]: To check definitions once methods finalised

2.1.1.1. Determine vehicle speed

Vehicle speed shall be determined by at least one of the following methods:

(a) a GNSS; if vehicle speed is determined by a GNSS, the total trip distance shall be checked by calculating and comparing the total trip distance with reference measurements obtained from either a sensor, the validated ECU or, alternatively, from a digital road network or topographic map. It is mandatory to correct GNSS data for obvious errors, e.g., by applying a dead reckoning sensor, prior to the consistency check. The original and uncorrected data file shall be retained and any corrected data shall be marked. The corrected data shall not exceed an uninterrupted time period of 120 s or a total of 300 s. The total trip distance as calculated from the corrected GNSS data shall deviate by no more than 4 per cent from the reference. If the GNSS data do not meet these requirements and no other reliable speed source is available, the test results shall be voided

(b) a sensor (e.g., optical or micro-wave sensor); if vehicle speed is determined by a sensor, the speed measurements shall comply with the accuracy requirements of ±1.0km/h absolute, or alternatively, the total trip distance determined by the sensor shall be compared with a reference distance obtained from a digital road network or topographic map. The total trip distance determined by the sensor shall deviate by no more than 4 per cent from the reference distance.

(c) the ECU; if vehicle speed is determined by the ECU, the total trip distance as determined by the EC can be compared with a reference distance obtained from a digital road network or topographic map. The total tri distance determined by the ECU shall deviate by no more than 4 per cent from the reference.

[Vehicle speed determined by the GNSS is considered the favourable option.]

2.1.1.2. Test room

If a test room is required to perform the pre-condition, soak and charge as described in paragraph 2.1.2.5. to 2.1.2.6. and depicted in Figure A3/1, the test cell shall have a temperature set point of 25 °C. The tolerance of the actual value shall be within ±5 °C.

[2.1.1.3. Cooling fan

A cooling fan shall be active if required to perform the tests as described in paragraphs 2.1.2.5. to 2.1.2.6., according to regional regulations for dynamometer testing

~~Regional regulations apply for the specifications and setting of the cooling fan, during the driving of the vehicle, if applicable.~~]

2.1.1.4. Soak area

The temperature of the soak area shall be maintained at 25 °C ±5 °C, if applicable.

2.1.1.5. Required information

[The manufacturer shall provide the information required to conduct the test procedure.]

~~[Boundary conditions that qualify vehicle for testing~~

- ~~Battery cell temperature normally distributed with average/minimum/maximum temperature at Y C and variance <Z~~
- ~~Average SOC normally distributed with average value Y*% and variance <Z*~~

- ~~Depth of discharge (DoD): share of cycles with DoD >Y**% must be below Z**%]~~

The manufacturer shall specify if a testing pure electric operation mode shall be set at vehicle level for performing the test of HD-OVC-HEVs.

~~If necessary to operate properly the vehicle, the vehicle's testing pure electric operation mode shall be activated by using the manufacturer's instruction.~~

The manufacturer shall provide the responsible authority a list of the deactivated devices and justification for the deactivation.

The testing operation mode shall be approved by the responsible authority and the use of a testing operation mode shall be recorded.

[The vehicle's testing operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions except for the internal battery heating-cooling system and the eventual eco mode automatically activated at the end of the depleting phase. The manufacturer shall provide evidence to the responsible authority]

[Any 'boost mode' shall be excluded to eliminate high currents requests]

2.1.1.6. Required measurements

The test vehicle shall be instrumented with measurement devices for measuring the necessary input values for the UBE calculation (voltage and electrical current). The external equipment shall be powered by an external power supply. The discharge and charge energy shall be measured at the battery to avoid combined battery-inverter efficiency and energy losses [based on manufacturer specifications and as demonstrated to the responsible authority.]

As an alternative to the use of voltage measurement devices, use of on-board measurement data is permissible if the accuracy and frequency of these data is demonstrated to the responsible authority to meet the minimum requirements for accuracy and frequency described in paragraph 1.2. of this annex.

The on-board measurement data of the voltage can be used during the in-service testing only when the accuracy and frequency of on-board measurement data is confirmed during the certification test and a safe inspection point is made available for the direct measurement verification.

A safe inspection point shall be made available for the direct measurement verification also during in-service testing.

2.1.1.7. Other information

The manufacturer shall specify the normal operating range for each operational metric listed in paragraph 2.1.2.1. of this annex[, if required].

[Regarding any testing operation mode (see paragraph 2.1.1.5. of this annex), the manufacturer shall provide a list of the deactivated devices and justification for the deactivation.]

2.1.2. Test sequence

2.1.2.1. General

The test shall be carried out in accordance with paragraphs 2.1.2.4. to 2.1.2.8. of this annex, (see Figure A3/1 and Figure A3/4). ~~The test shall be stopped immediately if warning indicator(s) with regard to the batteries turns on.~~

Breaks for the driver are permitted as prescribed in Table A3/3, but they shall be verified with region local authorities not to violate local legal rules.

Having more than one driver is permitted to comply with the short resting time (Table A3/3) needed to maintain the conditioning of the batteries.

Table A3/3
Breaks for the driver

Driving time (h)	*Maximum total break (min)*
every each 1h	10
More than 4h	Shall be based on the manufacturer's recommendation or regional authority

Note: During a break, the powertrain shall be switched off.

[The following operational metrics, if present [and if required], shall be monitored and recorded throughout the test: (a) battery temperature (minimum, maximum, as indicated by temperature of battery cells, modules, or pack, as available), (b) battery [state of charge (SOC) (from BMS and dashboard)], (c) battery cooling on/off, as available. The manufacturer shall specify the normal operating range for each operational metric [in case the operational metrics monitoring is applied].]

2.1.2.2. Preparation of vehicle

The vehicle shall be presented in good technical condition.

In case of certification the vehicle shall be run-in in accordance with the manufacturer's recommendations.

HD-PEVs and HD-OVC-HEVs shall have been run-in at least [300 km] or one full charge distance, whichever is longer.

In case of in-service conformity check the vehicle shall undergo to the acceptance check criteria defined in Annex 1 of this GTR.

2.1.2.3. Preparation of measurement devices

The measurement devices shall be installed at suitable and safe position(s) within the vehicle. The manufacturer shall recommend the measurement points with the approval of the responsible authority and with appropriate technical justification.

2.1.2.4. Initial setting of the battery

For HD-PEVs and HD-OVC-HEVs, prior to or during vehicle soak (paragraph 2.1.2.5. and 2.1.2.6. of this annex), the battery shall be charged/discharged to an initial [state of charge (SOC), as reported by the vehicle,] equal or less than 10 per cent as declared by the manufacturer. At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may specify a different initial SOC of the battery.

The battery shall be charged/discharged to the initial SOC in accordance with the procedure specified by the manufacturer for normal operation until the charging process is normally terminated.

The SOC shall be confirmed by a method provided by the manufacturer.

2.1.2.5. Vehicle pre-conditioning

The battery of the vehicle shall be discharged, left stabilised for a minimum of 30 minutes and maximum 1h and then fully charged [at a power less than or equal to the manufacturers recommendation for normal charging] before starting the test as specified in Figure A3/1.

The manufacturer may recommend a longer stabilisation time if necessary to ensure stabilisation of the high voltage battery.

This first battery discharge, referred to as pre-conditioning, shall be performed according to manufacturer's recommendation or given speed within the range of the characteristic regional speeds or C-rate without requirements on the ambient temperature. The manufacturer will guarantee that the battery is as fully depleted as possible by the discharge test procedure.

[The vehicle shall be installed for the preconditioning, if the battery discharge will be performed by driving in a test room.]

The end of discharge criterion is reached when the break-off criterion is met.

[In case of HD-PEV, if the battery is fully depleted by driving on-road, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance or experiences a driving power cut for 4 consecutive seconds or more.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here].

1. up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority.

2. up to the deactivation of the powertrain, i.e., no driving mode/traction is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3. Alternative is to introduce a voltage value

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

]

[In case of HD-OVC-HEVs ~~the pure electric vehicle test operation mode shall be selected~~. The break-off criterion is reached when

[~~the vehicle cannot drive in pure electric mode for 4 consecutive seconds or more without recuperation from the engine operation.~~

~~the $|\Delta E_{REESS,dt}|$ $|\Delta E_{REESS,dt}|$ $|\Delta E_{REESS,dt}|$ in the last xx dt of driving is equal to or less than xx per cent of the total nominal energy capacity of the battery/cumulative UBE.~~]

the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last [30 km] of driving is equal to or less than [2/3/5] per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \frac{UBE_{cumulative}}{total\ distance - \Delta km}$]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

~~If necessary to operate properly the vehicle, the vehicle's testing pure electric operation mode shall be activated by using the manufacturer's instruction.~~

~~The manufacturer shall provide the responsible authority a list of the deactivated devices and justification for the deactivation.~~

~~The testing operation mode shall be approved by the responsible authority and the use of a testing operation mode shall be recorded.~~

[~~The vehicle's testing operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions except for the internal battery heating-cooling system and the eventual eco mode automatically activated at the end of the depleting phase. The manufacturer shall provide evidence to the responsible authority~~]

[During the discharge of the battery, the operational metrics (see paragraph 2.1.2.1. of this annex) shall be recorded, if required.]

[~~To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges~~].

2.1.2.6. Vehicle soak and charge

The soak and charge is performed in the soak area or test room if available.

If the soak and charge is performed in a soak area or test cell the soak area temperature during soak shall be as specified in [paragraph 2.1.1.4. of this annex].

It is allowed to operate a battery internal [pre-warming] system if available, recording the energy consumption for all the soak and charge duration. External [pre-warming] systems, different from charging stations, are not allowed.

The external equipment such as the charging station shall be powered by an external power supply.

Measurement devices installed within the vehicle shall be warmed up as appropriate.

The measurement devices shall start collecting data.

~~[The battery shall be fully charged with the highest normal charging power available according to vehicle specification [≤150kW250kW].~~

~~The battery shall be charged at full with the highest normal charging power recommended by the manufacture according to vehicle specification or [≤2150kW] whichever is less.~~

~~[≤250kW] Or the maximum normal charging power allowed by manufacture]~~

The battery shall be fully charged at a power less than or equal to the manufacturers recommendation for normal charging.

Record the charge current and voltage and the elapsed time required to reach the fully charge battery.

The vehicle shall be soaked for a minimum of 6 hours and a maximum of 36 hours to ensure temperature stabilisation of the high voltage battery.

~~The manufacturer may recommend a specific soak and charge time within the range of [6 to 36 hours] if necessary to ensure temperature stabilisation of the high voltage battery.~~

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

[Fully charged battery status shall be reached. If the selected power charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging unplugging and plugging again the vehicle if needed with/without waiting time between the two charges.]

[The temperature of the battery shall be checked before starting the test.

It is allowed to extend the soak and charge time to stabilise the temperature of the battery]

[If the soak and charge is performed in a soak area, the vehicle shall not receive unjustified exposure to other temperatures but if that is unavoidable this time should in any case be limited to a maximum of [10] minutes.]

[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].

2.1.2.7. Method 1a test

The actual test run shall start within a period of 1 hour after the disconnection of the vehicle from the grid, otherwise the preconditioning and charge shall be repeated.

The test shall be carried out on a test track with the regional characteristic speeds and payload per Gross Vehicle Mass (GVM) and Gross Train Mass (GTM) in agreement with the responsible authorities.

The battery shall be discharged preferably with a constant speed within the range of the characteristic regional speeds up to a battery [state of charge (SOC), as reported by the vehicle,] equal or less to 10 per cent.

In the remaining part of the depleting test the battery shall be discharged with a target constant speed per Gross Vehicle Mass (GVM) and Gross Train Mass (GTM) in agreement with the responsible authorities with a speed tolerance of [± 7km/h] according to specification of paragraph 2.1.1.1. of this annex.

During the test, the speed can be controlled manually or by cruise control system if available.

The acceleration and deceleration during vehicle speed change shall be smooth and accomplished within the range ± [0.5-1] km/h/sec as recommendation.

The end of discharge criterion is reached when the break-off criterion is met. The break-off criterion is reached when the vehicle exceeds the driving speed tolerance for 4 consecutive seconds or more.

The end of discharge criterion is reached when the break-off criterion is met.

[In case of HD-PEV, if the battery is fully depleted by driving on-road, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance or experiences a driving power cut for 4 consecutive seconds or more.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here]

1 up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority.

2 up to the deactivation of the powertrain, i.e., no driving mode/traction is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3 Alternative is to introduce a voltage cut-off value

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

]

[In case of HD-OVC-HEVs ~~the pure electric vehicle test operation mode shall be selected.~~ The break-off criterion is reached when

~~[the vehicle cannot drive in pure electric mode for 4 consecutive seconds or more without recuperation from the engine operation.]~~

~~the $|\Delta E_{REESS,dt}|$ in the last xx dt of driving is equal to or less than xx per cent of the total nominal energy capacity of the battery/cumulative UBE.~~

[the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last xx km of driving is equal to or less than xx per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \frac{UBE_{cumulative}}{total\ distance - \Delta km}$]

]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

The $UBE_{~~[discharge]~~}$ is the total discharged energy calculated as described in paragraph 3. of this annex.

The HD-PEV and HD-OVC-HEV shall be connected to the mains within 120 minutes after coming to a standstill, if required.

The battery shall be fully charged, if required, at a power less than or equal to the manufacturers recommendation for normal charging.

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

[If the selected power charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging power, unplugging and plugging again the vehicle, with/without waiting time between the two charges .]

[The UBE_{charge} is the total charged energy [calculated as described in paragraph 3. of this annex].]

[~~The full cycle efficiency is calculated by dividing the $UBE_{discharge}$ by the UBE_{charge}.~~]

[The test Method 1a is performed on new vehicles within a family, if applicable, to determine the $UBE_{certified}$[~~, defined as $UBE_{discharge,cert.}$~~].]

[The test Method 1a is performed on aged vehicles within a family to determine the $UBE_{measured}$ [~~, defined as $UBE_{discharge,meas}$~~].]

The $SOCE_{measured}$ is derived according to paragraph [6.3.2. of this GTR].

2.1.2.8. End of Method 1a test

At the end of the Method 1a test, the measured values and the operational metrics (see paragraph 2.1.2.1. of this annex) shall be recorded.

After the measurements are complete, the vehicle and measurement devices shall be stopped.

2.2 Method 1b: Discharge by driving on the road [~~with average speed~~]

2.2.1. General test requirements

[In Method 1b the battery shall be depleted by driving the vehicle on the road as specified in this paragraph of this annex with speeds [~~and tolerances~~] as specified in paragraph [2.2.2.7.].]

The manufacturer shall guarantee that all the traction batteries installed on the vehicle are engaged during the test to determine the Usable Battery Energy (UBE) certified and measured.

[The road surface shall have a texture and composition representative of current urban and highway road surfaces, i.e. no airstrip-specific surface].

2.2.1.1. Determine vehicle speed

Vehicle speed shall be determined by at least one of the following methods:

(a) a GNSS; if vehicle speed is determined by a GNSS, the total trip distance shall be checked by calculating and comparing the total trip distance with reference measurements obtained from either a sensor, the validated ECU or, alternatively, from a digital road network or topographic map. It is mandatory to correct GNSS data for obvious errors, e.g., by applying a dead reckoning sensor, prior to the consistency check. The original and uncorrected data file shall be retained and any corrected data shall be marked. The corrected data shall not exceed an uninterrupted time period of 120 s or a total of 300 s. The total trip distance as calculated from the corrected GNSS data shall deviate by no more than 4 per cent from the reference. If the GNSS data do not meet these requirements and no other reliable speed source is available, the test results shall be voided

(b) a sensor (e.g., optical or micro-wave sensor); if vehicle speed is determined by a sensor, the speed measurements shall comply with the accuracy requirements of ±1.0km/h absolute, or alternatively, the total trip distance determined by the sensor shall be compared with a reference distance obtained from a digital road network or topographic map. The total trip distance determined by the sensor shall deviate by no more than 4 per cent from the reference distance.

(c) the ECU; if vehicle speed is determined by the ECU, the total trip distance as determined by the EC can be compared with a reference distance obtained from a digital road network or topographic map. The total tri distance determined by the ECU shall deviate by no more than 4 per cent from the reference.

[Vehicle speed determined by the GNSS is considered the favourable option.]

2.2.1.2. Test room

If a test room is required to perform the tests as described in paragraphs [2.2.2.5. to 2.2.2.6.].and depicted in Figure A3/2, the test cell shall have a temperature set point of [25] °C. The tolerance of the actual value shall be within ±5 °C.

[2.2.1.3. Cooling fan

A cooling fan shall be active if required to perform the tests as described in paragraphs [2.2.2.5. to 2.2.2.6.], according to regional regulations for dynamometer testing

~~Regional regulations apply for the specifications and setting of the cooling fan, during the driving of the vehicle, if applicable.~~]

2.2.1.4. Soak area

The temperature of the soak area shall be maintained at [25 °C ±5 °C], if applicable.

2.2.1.5. Required information

[The manufacturer shall provide the information required to conduct the test procedure.]

~~[Boundary conditions that qualify vehicle for testing~~

- ~~Battery cellcell temperature normally distributed with average temperature at Y C and variance <Z~~
- ~~Average SOC normally distributed with average value Y*% and variance <Z*~~
- ~~Depth of discharge (DoD): share of cycles with DoD >Y**% must be below Z**%]~~

[The manufacturer shall specify if a testing pure electric operation mode shall be set at vehicle level for performing the test of HD-OVC-HEVs.]

~~If necessary to operate properly the vehicle, the vehicle's testing pure electric operation mode shall be activated by using the manufacturer's instruction.~~

The manufacturer shall provide the responsible authority a list of the deactivated devices and justification for the deactivation.

The testing operation mode shall be approved by the responsible authority and the use of a testing operation mode shall be recorded.

[The vehicle's testing operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions except for the internal battery heating-cooling system and the eventual eco mode automatically activated at the end of the depleting phase. The manufacturer shall provide evidence to the responsible authority]

[Any 'boost mode' shall be excluded to eliminate high currents requests.]

2.2.1.6. Required measurements

The test vehicle shall be instrumented with measurement devices for measuring the necessary input values for the UBE calculation (voltage and electrical current). The external equipment shall be powered by an external power supply. The discharge and charge energy shall be measured at the battery to avoid combined battery-inverter efficiency and energy losses based on manufacturer specifications and as demonstrated to the responsible authority.

As an alternative to the use of voltage measurement devices, use of on-board measurement data is permissible if the accuracy and frequency of these data is demonstrated to the responsible authority to meet the minimum requirements for accuracy and frequency described in paragraph 1.2. of this annex.

The on-board measurement data of the voltage can be used during the in-service testing only when the accuracy and frequency of on-board measurement data is confirmed during the certification Test and a safe inspection point is made available for the direct measurement verification.

A safe inspection point shall be made available for the direct measurement verification also during in-service testing.

2.2.1.7. Other information

The manufacturer shall specify the normal operating range for each operational metric listed in paragraph 2.2.2.1. of this annex.

[Regarding any testing operation mode (see paragraph 2.2.1.5. of this annex), the manufacturer shall provide a list of the deactivated devices and justification for the deactivation.]

2.2.2. Test sequence

2.2.2.1. General

The test shall be carried out in accordance with paragraphs 2.2.2.4. to 2.2.2.8. of this annex, (see Figure A3/2 and Figure A3/4).[~~The test shall be stopped immediately if warning indicator(s) with regard to the batteries turns on~~].

Breaks for the driver are permitted as prescribed in Table A3/4, but they shall be verified with region local authorities not to violate local legal rules.

Having more than one driver is permitted to comply with the short resting time (Table A3/4) needed to maintain the conditioning of the batteries.

Table A3/4
Breaks for the driver

Driving time (h)	*Maximum total break (min)*
every each 1h	10
More than 4h	Shall be based on the manufacturer's recommendation or regional authority

Note: During a break, the powertrain shall be switched off.

[The following operational metrics, if present [and if required], shall be monitored and recorded throughout the test: (a) battery temperature (minimum, maximum, as indicated by temperature of battery cells, modules, or pack, as available), (b) battery state of charge (from BMS and dashboard), (c) battery cooling on/off, as available. The manufacturer shall specify the normal operating range for each operational metric [in case the operational metrics monitoring is applied].]

2.2.2.2. Preparation of vehicle

The vehicle shall be presented in good technical condition.

In case of certification, the vehicle shall be run-in in accordance with the manufacturer's recommendations.

HD-PEVs and HD-OVC-HEVs shall have been run-in at least 300 km or one full charge distance, whichever is longer.

In case of in-service conformity check the vehicle shall undergo to the acceptance check criteria defined in Annex 1 of this GTR.

2.2.2.3. Preparation of measurement devices

The measurement devices shall be installed at suitable and safe position(s) within the vehicle. The manufacturer shall recommend the measurement points with the approval of the responsible authority and with appropriate technical justification.

2.2.2.4. Initial setting of the battery

For HD-PEVs and HD-OVC-HEVs, prior to or during vehicle soak (paragraphs 2.2.2.5 and 2.2.2.6. of this annex), the battery shall be charged/discharged to an initial [state of charge (SOC), as reported by the vehicle,] equal or less than 10 per cent as declared by the manufacturer. At the request of the manufacturer, with the approval of the responsible

authority and with appropriate technical justification, the manufacturer may specify a different initial SOC of the battery.

The battery shall be charged/discharged to the initial SOC in accordance with the procedure specified by the manufacturer for normal operation until the charging process is normally terminated.

The SOC shall be confirmed by a method provided by the manufacturer.

2.2.2.5. Vehicle pre-conditioning

The battery of the vehicle shall be discharged, left stabilised for a minimum of 30 minutes and maximum 1h and then fully charged at normal charge before starting the test as specified in Figure A3/2.

The manufacturer may recommend a longer stabilisation time if necessary to ensure stabilisation of the high voltage battery.

This first battery discharge, referred to as pre-conditioning, shall be performed according to manufacturer's recommendation or given speed within the range of the characteristic regional speeds or C-rate without requirements on the ambient temperature. The manufacturer will guarantee that the battery is as fully depleted as possible by the discharge test procedure.

The vehicle shall be installed for the preconditioning, if the battery discharge will be performed by driving in a test room.

The end of discharge criterion is reached when the break-off criterion is met.

[In case of HD-PEV, if the battery is fully depleted by driving on-road, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance or experiences a driving power cut for 4 consecutive seconds or more.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here]

1 up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority.

2 up to the deactivation of the powertrain, i.e., no driving mode/traction is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3 Alternative is to introduce a voltage value

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.]

[In case of HD-OVC-HEVs ~~the pure electric vehicle test operation mode shall be selected.~~ The break-off criterion is reached when ….

~~[the vehicle cannot drive in pure electric mode for 4 consecutive seconds or more without recuperation from the engine operation.]~~

~~the $|\Delta E_{REESS,dt}|$ in the last xx dt of driving is equal to or less than xx per cent of the total nominal energy capacity of the battery/cumulative UBE.~~

[the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last xx km of driving is equal to or less than xx per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \frac{UBE_{cumulative}}{total\ distance - \Delta km}$]

]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

~~If necessary to operate properly the vehicle, the vehicle's testing pure electric operation mode shall be activated by using the manufacturer's instruction.~~

~~The manufacturer shall provide the responsible authority a list of the deactivated devices and justification for the deactivation.~~

~~The testing operation mode shall be approved by the responsible authority and the use of a testing operation mode shall be recorded.~~

~~[The vehicle's testing operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions except for the internal battery heating-cooling system and the eventual eco mode automatically activated at the end of the depleting phase. The manufacturer shall provide evidence to the responsible authority.]~~

[During the discharge of the battery, the operational metrics (see paragraph 2.2.2.1. of this annex) shall be recorded.]

~~[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].~~

2.2.2.6. Vehicle soak and charge

The soak and charge is performed in the soak area or test room if available.

If the soak and charge is performed in a soak area or test cell the soak area temperature during soak shall be as specified in [paragraph 2.2.1.4. of this annex].

It is allowed to operate a battery internal [pre-warming] system if available, recording the energy consumption for all the soak and charge duration.

External [pre-warming] systems, different from charging stations, are not allowed.

The external equipment such as the charging station shall be powered by an external power supply.

Measurement devices installed within the vehicle shall be warmed up as appropriate.

The measurement devices shall start collecting data.

The battery shall be fully charged at a power less than or equal to the manufacturers recommendation for normal charging.

~~The battery shall be charged at full with the highest normal charging power available according to vehicle specification ≤150kW~~ Record the charge current and voltage and the elapsed time required to reach the fully charge battery.

The vehicle shall be soaked for a minimum of 6 hours and a maximum of 36 hours to ensure temperature stabilisation of the high voltage battery.

~~The manufacturer may recommend a specific soak and charge time within the range of [6 to 36 hours] if necessary to ensure temperature stabilisation of the high voltage battery.~~

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

[Fully charged battery status shall be reached. If the selected power/c-rate charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging unplugging and plugging again the vehicle with/without waiting time between the two charges.]

[The temperature of the battery shall be checked before starting the test.

It is allowed to extend the soak and charge time to stabilise the temperature of the battery]

[If the soak and charge is performed in a soak area, the vehicle shall not receive unjustified exposure to other temperatures but if that is unavoidable this time should in any case be limited to a maximum of [10] minutes.]

[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].

2.2.2.7. Method 1b test

The actual test run shall start within a period of 1 hour after the disconnection of the vehicle from the grid, otherwise the preconditioning and charge shall be repeated.

The test shall be carried out on road with the regional characteristic speeds and payload per Gross Vehicle Mass (GVM) and Gross Train Mass (GTM) in agreement with the responsible authorities [and not exceeding xx per cent of the GVM/GTM.]

The battery shall be discharged up to a minimum battery state of charge in agreement with the local regional authority and safety rules.

The same route can be used at certification and Part A verification in accordance with regional authority, if applicable.

During the test, the speed can be controlled manually or by cruise control system if available.

The acceleration and deceleration during vehicle speed change shall be as smooth as possible in relation to traffic conditions and safety of driving and accomplished within the range ±[0.5-1] km/h/sec as recommendation if applicable.

The proportional cumulative positive altitude gain over the entire trip shall be less than 1,200m / 100km and be determined according to regional regulations, for instance, referring to UN Regulation No 168 as example.

The end of discharge criterion is reached when the break-off criterion is met.

[In case of HD-PEV, if the battery is fully depleted by driving on-road, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance or experiences a driving power cut for 4 consecutive seconds or more.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here]

1 up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority.

2 up to the deactivation of the powertrain, i.e., no driving mode/traction is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3 Alternative is to introduce a voltage value]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

[In case of HD-OVC-HEVs ~~the pure electric vehicle test operation mode shall be selected.~~ The break-off criterion is reached when …

~~[the vehicle cannot drive in pure electric mode for 4 consecutive seconds or more without recuperation from the engine operation.]~~

~~the $|\Delta E_{REESS,dt}|$ in the last xx dt of driving is equal to or less than xx per cent of the total nominal energy capacity of the battery/cumulative UBE. The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.~~

[the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last xx km of driving is equal to or less than xx per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \ \frac{UBE_{cumulative}}{total\ distance - \Delta km}$$]

]

The $UBE_{[discharge]}$ is the total discharged energy calculated as described in paragraph 3. of this annex.

The HD-PEV and HD-OVC-HEV shall be connected to the mains within 120 minutes after coming to a standstill, if required.

The battery shall be fully charged, if required, at a power less than or equal to the manufacturers recommendation for normal charging.

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

If the selected power charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging power unplugging and plugging again the vehicle with/without waiting time between the two charges.

[The UBE_{charge} is the total charged energy [calculated as described in paragraph 3. of this annex].]

~~The full cycle efficiency is calculated by dividing the $UBE_{discharge}$ by the UBE_{charge}.~~

[The test Method 1b is performed on [new vehicles within a family], if applicable, to determine the $UBE_{certified}$~~[, defined as [$UBE_{discharge,cert}$]]~~.

The test Method 1b is performed on [aged vehicles within a family] to determine the $UBE_{measured}$~~[, defined as [$UBE_{discharge,meas}$]]~~.

The $SOCE_{measured}$ is derived according to paragraph [6.3.2. of this GTR]

2.2.2.8. End of Method 1b test

At the end of the Method 1b test, the measured values and the operational metrics (see paragraph 2.2.2.1. of this annex) shall be recorded.

After the measurements are complete, the vehicle and measurement devices shall be stopped.

2.3. Method 2: Discharge by a bidirectional power supply system

2.3.1. General test requirements

In Method 2 a Virtual Round Trip Efficiency (VRTE) test (fully discharge – fully charge cycle) is applied to the battery by a bidirectional power supply unit after pre-conditioning.

The manufacturers shall guarantee that all the traction batteries installed on the vehicle are engaged during the test to determine the Usable Battery Energy (UBE) certified and measured [and that they must perform within the same operating limits as in the driving mode].

[A bidirectional power supply is a power converter that can convert DC and AC power bi-directionally to any power system~~. It supports both DC and AC by mounting a bidirectional DC/DC converter and a bidirectional AC/DC converter inside.~~]

2.3.1.1. Test room

The test cell shall have a temperature set point of [25] °C. The tolerance of the actual value shall be within ±5 °C.

2.3.1.2. [Cooling fan

A cooling fan shall be active if required to perform the tests as described in paragraph 2.3.2.5. to 2.3.2.8., according to regional regulations for dynamometer testing if applicable.

~~Regional regulations apply for the specifications and setting of the cooling fan, during the driving of the vehicle, if applicable.~~]

2.3.1.3. Soak area

The temperature of the soak area shall be maintained at [25 °C ±5 °C].

2.3.1.4. Required information

The manufacturer shall provide the information required to conduct the test procedure.

~~[Boundary conditions that qualify vehicle for testing~~

- ~~Battery cellcell temperature normally distributed with average temperature at Y C and variance <Z~~
- ~~Average SOC normally distributed with average value Y*% and variance <Z*~~
- ~~Depth of discharge (DoD): share of cycles with DoD >Y**% must be below Z**%]~~

[The manufacturer shall specify if a ~~VRTE~~ [bidirectional] operation mode shall be set at vehicle level for performing the test, [prove given that the operating window] for two-way discharge is identical to that for driving.]

2.3.1.5. Required measurements

The test vehicle shall be instrumented with measurement devices for measuring the necessary input values for the UBE calculation (voltage and

electrical current). The discharge and charge energy shall be measured at the battery to avoid combined battery-inverter efficiency and energy losses based on manufacturer specifications and as demonstrated to the responsible authority.

As an alternative to the use of voltage measurement devices, use of on-board measurement data is permissible if the accuracy and frequency of these data is demonstrated to the responsible authority to meet the minimum requirements for accuracy and frequency described in paragraph 1.2. of this annex.

The on-board measurement data of the voltage can be used during the in-service testing only when the accuracy and frequency of on-board measurement data is confirmed during the certification Test and a safe inspection point is made available for the direct measurement verification.

A safe inspection point shall be made available for the direct measurement verification also during in-service testing.

2.3.1.6. Other information

The manufacturer shall specify the normal operating range for each operational metric listed in paragraph 2.3.2.1. of this annex.

[Regarding any bi-directional operation mode (see paragraph [2.3.1.4.] of this annex), the manufacturer shall provide a list of the deactivated devices and justification for the deactivation.]

2.3.2. Test sequence

2.3.2.1. General

The test shall be carried out in accordance with [paragraphs 2.3.2.4. to 2.3.2.8. of this annex], (see Figure A3/3 and Figure A3/4). ~~The test shall be stopped immediately if warning indicator(s) with regard to the batteries turns on~~.

[The following operational metrics, if present [and required], shall be monitored and recorded throughout the test: (a) battery temperature (minimum, maximum, as indicated by maximum temperature of battery cells, modules, or pack, as available), (b) battery state of charge (from BMS and dashboard), (c) battery cooling on/off, as available. The manufacturer shall specify the normal operating range for each operational metric [in case the operational metrics monitoring is applied].]

2.3.2.2. Preparation of vehicle

The vehicle shall be presented in good technical condition.

In case of certification, the vehicle shall be run-in in accordance with the manufacturer's recommendations.

HD-PEVs and HD-OVC-HEVs shall have been run-in at least 300 km or one full charge distance, whichever is longer.

In case of in-service conformity check the vehicle shall undergo to the acceptance check criteria defined in Annex 1 of this GTR.

2.3.2.3. Preparation of measurement devices

The measurement devices shall be installed at suitable and safe position(s) within the vehicle. The manufacturer shall recommend the measurement points with the approval of the responsible authority and with appropriate technical justification.

2.3.2.4. Initial setting of the battery

For HD-PEVs and HD-OVC-HEVs, prior to or during vehicle soak (paragraphs 2.3.2.5. and 2.3.2.6. of this annex), the battery shall be

charged/discharged to an initial [state of charge (SOC), as reported by the vehicle,] equal or less than 10 per cent as declared by the manufacturer. At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may specify a different initial SOC of the battery.

The battery shall be charged/discharged to the initial SOC in accordance with the procedure specified by the manufacturer for normal operation until the charging process is normally terminated.

The SOC shall be confirmed by a method provided by the manufacturer.

2.3.2.5. Vehicle and bidirectional charger installation and pre-conditioning

The battery of the vehicle shall be discharged, left stabilised for a minimum of 30 minutes and maximum 1h and then fully charged at normal charge before starting the test as specified in Figure A3/3.

The manufacturer may recommend a longer stabilisation time if necessary to ensure stabilisation of the high voltage battery.

The vehicle and the bidirectional charger shall be installed for the preconditioning if the first discharge of the battery is performed with a bidirectional system.

The bidirectional charger shall be [conditioned] or [warmed up in accordance with the manufacturer's recommendations], as appropriated, so that the internal electrical systems may be stabilised. Auxiliary devices of the vehicle shall be switched off or deactivated during bidirectional charge.

If necessary to operate properly the bidirectional charger, the vehicle's bidirectional charge operation mode shall be activated by using the manufacturer's instruction.

The manufacturer shall provide the responsible authority a list of the deactivated devices and justification for the deactivation. The bidirectional charge operation mode shall be approved by the responsible authority and the use of a bidirectional charge operation mode shall be recorded.

The vehicle's bidirectional charge operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions, except for the internal battery heating-cooling system. The manufacturer shall provide evidence to the responsible authority

This first battery discharge, referred to as pre-conditioning, shall be performed according to manufacturer's recommendation or given power or C-rate within the range of the characteristic regional speeds without requirements on the ambient temperature. The manufacturer will guarantee that the battery is as fully depleted as possible by the discharge test procedure.

The end of discharge criterion is reached when the break-off criterion is met.

[The break-off criterion is reached when [an indication to stop the system appears on the instrument panel], or [the system cannot maintain the set power any longer].]

~~[(exceeds the tolerance defined as the power corresponding at the minimum speed of Method1a or 1b for 4 consecutive seconds or more) ~~]

[If the discharge is performed driving the vehicle, in case of HD-PEV, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance or experiences a driving power cut for 4 consecutive seconds or more.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here]

1 up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority.

2 up to the deactivation of the powertrain, i.e., no driving mode/traction is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3 Alternative is to introduce a voltage value]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

[In case of HD-OVC-HEVs ~~the pure electric vehicle test operation mode shall be selected. T~~he break-off criterion is reached when

~~[the vehicle cannot drive in pure electric mode for 4 consecutive seconds or more without recuperation from the engine operation.]~~

~~the $|\Delta E_{REESS,dt}|$ in the last xx dt of driving is equal to or less than xx per cent of the total nominal energy capacity of the battery/cumulative UBE.~~

[the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last xx km of driving is equal to or less than xx per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \ \frac{UBE_{cumulative}}{total\ distance - \Delta km}$$]

]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

If necessary to operate properly the vehicle, the vehicle's testing pure electric operation mode shall be activated by using the manufacturer's instruction.

The manufacturer shall provide the responsible authority with a list of the deactivated devices and justification for the deactivation.

The testing operation mode shall be approved by the responsible authority and the use of a testing operation mode shall be recorded.

The vehicle's testing operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions except for the internal battery heating-cooling system and the eventual eco mode automatically activated at the end of the depleting phase. The manufacturer shall provide evidence to the responsible authority

[During the discharge of the battery, the operational metrics (see paragraph 2.3.2.1. of this annex) shall be recorded.]

[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].

2.3.2.6. Vehicle soak and charge

The soak and charge is performed in the soak area or test room if available.

The battery shall be recharged with the bidirectional power supply system or a charging station.

If the soak and charge is performed in a soak area or test cell the soak area temperature during soak shall be as specified in paragraph 2.3.1.3. of this annex.

It is allowed to operate a battery internal [pre-warming] system if available, recording the energy consumption for all the soak and charge duration. External [pre-warming] systems, different from charging stations, are not allowed.

The external equipment such as the charging station or the bidirectional power supply system shall be powered by an external power supply.

Measurement devices installed within the vehicle shall be warmed up as appropriate.

The measurement devices shall start collecting data.

The battery shall be fully charged at a power less than or equal to the manufacturers recommendation for normal charging, ~~The battery shall be charged at full with the highest normal charging power available according to vehicle specification [≤150kW~~by the bidirectional power supply system or a charging station. Record the charge current and voltage and the elapsed time required to reach the fully charge battery.

The vehicle shall be soaked for a minimum of 6 hours and a maximum of 36 hours to ensure temperature stabilisation of the high voltage battery.

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

~~[In the case in which the charge is performed with the bi-directional power supply the battery shall be charged at full at constant power/C-rate equal or less than C/5, according to operating limits or the highest normal charging power available according to vehicle specification [≤150kW]].~~

[Fully charged battery status shall be reached. If the battery is recharged with a charging station and the selected power/c-rate charging does not allow to reach the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging unplugging and plugging again the vehicle with/without waiting time between the two charges.]

[The temperature of the battery shall be checked before starting the test.

It may be allowed to extend the soak and charge time to stabilise the temperature of the battery]

If the soak and charge is performed in a soak area, the vehicle shall not receive unjustified exposure to other temperatures but if that is unavoidable this time should in any case be limited to a maximum of [10] minutes.

[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].

2.3.2.7. Method 2 test

The actual test run shall start within a period of 1 hour after the disconnection of the vehicle from the grid, otherwise the preconditioning and charge shall be repeated.

[If the same instrument is used both for charging and discharging the battery of the vehicle, the actual test run shall start within a period of 1 hour after the setting of the bidirectional power supply system in the discharging mode,

with or without the disconnection of the system according to the operational instruction of the system].

[The test shall be carried out with a power range derived from the regional characteristic speed and payload per Gross Vehicle Mass (GVM) and Gross Train Mass (GTM) in agreement with the responsible authorities as in Method 1a.]

~~[The battery shall be discharged with [a constant power or constant C-rate within the range of the characteristic regional speeds], [duplicate at least minimum and maximum speed].]~~

~~[Not to have unwanted battery behaviour operating strategy as near as possible to driving strategy the corresponding C-rate shall be in the range of [C/6 or less, C/2], otherwise the test shall be repeated.]~~

The end of discharge criterion is reached when the break-off criterion is met.

[The break-off criterion is reached when~~[an indication to stop the vehicle appears on the instrument panel]~~, or [the system cannot maintain the set power any longer].

~~The end of discharge criterion is reached when [the cut-off voltage/ threshold as defined by the manufacturer prior to conducting the test is reached~~].

]

The $UBE_{[discharge]}$ is the total discharged energy calculated as described in paragraph 3. of this annex.

The HD-PEV and HD-OVC-HEV shall be connected to the mains within 120 minutes after coming to a standstill, if required.

~~[The battery shall be fully charged with a defined [constant power/C-rate] equal or less than C/5 according to operating limits or the highest normal charging power available according to vehicle specification ≤150kW.]~~

The battery shall be fully charged, if required, at a power less than or equal to the manufacturers recommendation for normal charging.

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

If the selected power charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging power with/without waiting time between the two charges.

[The UBE_{charge} is the total charged energy [calculated as described in paragraph 3. of this annex.]]

~~[The full cycle efficiency is calculated by dividing the $UBE_{discharge}$ by the UBE_{charge}.]~~

The test Method 2 is performed on new vehicles within a family, if applicable, to determine the $UBE_{certified}$ ~~[, defined as [$UBE_{discharge,cert}$]].~~

The test Method 2 is performed on [aged vehicles within a family] to determine the $UBE_{measured}$ ~~[, defined as [$UBE_{discharge,meas}$]]~~.

The $SOCE_{measured}$ is derived according to paragraph [6.3.2. of this GTR]

For HD-OVC-HEV the internal combustion engine shall not operate during the duration of the test.

2.3.2.8. End of the Method 2 test

At the end of the Method 2 test, the measured values and the operational metrics (see paragraph 2.3.2.1. of this annex) shall be recorded.

After the measurements are complete, the vehicle and measurement devices shall be stopped.

Figure A3/1
Test sequence Method 1a

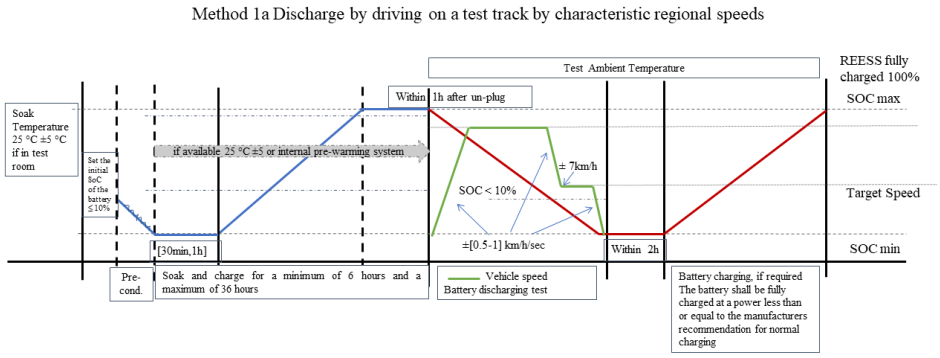


Figure A3/2
Test sequence Method 1b

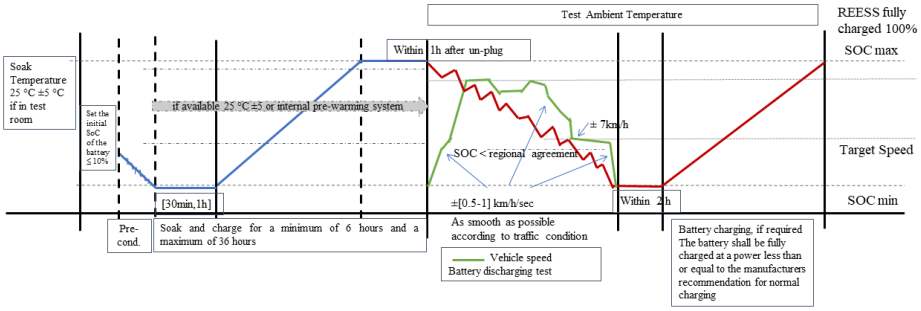


Figure A3/3
Test sequence Method 2

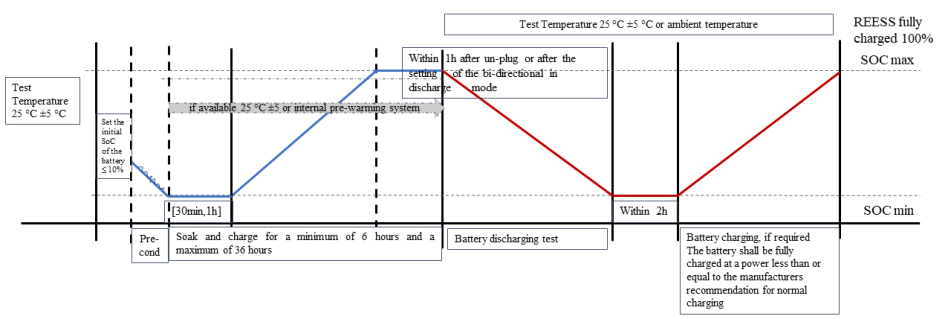
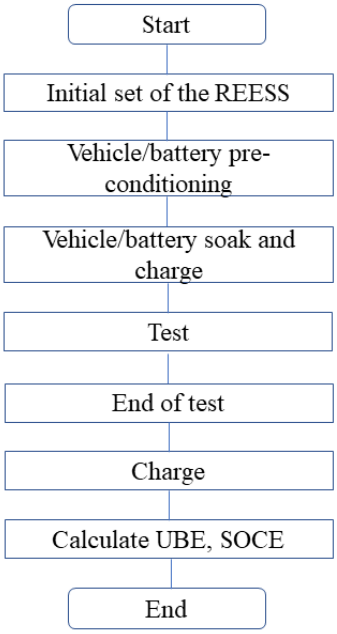


Figure A3/4
Test sequence



[

2.4. Alternative method: Constant and transient cycles test method by using HD chassis dynamometer

2.4.1. General test requirements

In the Alternative Method the battery shall be depleted by a cycles test method by driving the vehicle on a HDV chassis dynamometer after pre-conditioning.

[This method allows both constant speed test and transient condition test on HD chassis dynamometer.]

The manufacturer shall guarantee that all the traction batteries installed on the vehicle are engaged during the test to determine the Usable Battery Energy (UBE) certified and measured.

The road load dyno setting, the measurement points together with the test cycle must be identical at certification and during in-service testing Part A verification [if the alternative method is applied] for the SOCE monitor family concerned.

~~[A section of constant speed driving is allowed to stabilise the SOC of the battery during the depleting test]~~

2.4.1.1. Dynamometer

2.4.1.1.1. Dynamometer road load coefficient setting

[During the test, the resistance coefficient obtained from coasting test or the recommended resistance value shall be used for the chassis dynamometer setting conditions. The recommended value shall be determined in agreement with the local authorities.]

[The chassis dynamometer setting and test shall be carried out according to the regional regulations. As term of example, referring to the Title 40 of the Code of Federal Regulation, to the China stage 3 and 4 vehicle tests for fuel consumption determination, to the vehicle data as described in (EU) 2017/2400 and others.]

Commented [JRC 756]: Any Japan regional requirement to add?

2.4.1.1.2. Coasting resistance measurement

Coasting resistance measurement will follow regional regulations.

2.4.1.1.3. Coasting resistance calculation

The coasting resistance calculation will follow the regional regulations.

2.4.1.1.4. Chassis dynamometer settings

Chassis dynamometer settings will follow regional regulations.

2.4.1.1.5. The chassis dynamometer shall meet the structural and functional requirements as set in the regional regulations.

2.4.1.1.6. The accuracy of the chassis dynamometer shall meet the regional regulations.

2.4.1.2. Test room

The test cell shall have a temperature set point of 25°C. The tolerance of the actual value shall be within ±5°C.

2.4.1.3. Cooling fan

[When testing with a chassis dynamometer in the alternative method, the fan shall synchronise with the speed of the vehicle and follow the regional regulations for what concerns the minimum requirements for the fan outlet and the maximum deviation from air velocity related to the driving velocity. For example the deviation between the wind speed of the simulated fan and the speed of the car should not be greater than ± 5 km/h].

2.4.1.4. Soak area

The temperature of the soak area shall be maintained at [25 °C ±5°C].

2.4.1.5. Required information

The manufacturer shall provide the information required to conduct the test procedure.

~~[Boundary conditions that qualify vehicle for testing~~

- ~~Battery cell temperature normally distributed with average temperature at Y C and variance <Z~~
- ~~Average SOC normally distributed with average value Y*% and variance <Z*~~
- ~~Depth of discharge (DoD): share of cycles with DoD >Y**% must be below Z**%]~~

The manufacturer shall specify if a testing operation mode shall be set at vehicle level for performing the test.

~~[If necessary to operate properly the vehicle, the vehicle's testing pure electric operation mode shall be activated by using the manufacturer's instruction.]~~

The manufacturer shall provide the responsible authority a list of the deactivated devices and justification for the deactivation.

The testing operation mode shall be approved by the responsible authority and the use of a testing operation mode shall be recorded.

[The vehicle's testing operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the battery energy throughput under the test conditions except for the internal battery heating-cooling system and the eventual eco mode automatically activated at the end of the depleting phase. The manufacturer shall provide evidence to the responsible authority] .

2.4.1.6. Required measurements

The test vehicle shall be instrumented with measurement devices for measuring the necessary input values for the UBE calculation (voltage and electrical current). The external equipment shall be powered by an external power supply. The discharge and charge energy shall be measured at the battery to avoid combined battery-inverter efficiency and energy losses based on manufacturer specifications and as demonstrated to the responsible authority.

As an alternative to use of measurement devices, use of voltage on-board measurement data is permissible if the accuracy and frequency of these data is demonstrated to the responsible authority to meet the minimum requirements for accuracy and frequency described in paragraph 1.2. of this annex

The on-board measurement data of the voltage can be used during the in-service testing only when the accuracy and frequency of on-board measurement data is confirmed during the certification Test and a safe inspection point is made available for the direct measurement verification.

A safe inspection point shall be made available for the direct measurement verification also during in-service testing.

2.4.1.7. Other information

The manufacturer shall specify the normal operating range for each operational metric listed in paragraph 2.4.2.1. of this annex.

[Regarding any testing operation mode (see paragraph 2.4.1.5. of this annex), the manufacturer shall provide a list of the deactivated devices and justification for the deactivation.]

[2.4.2. Test sequence

2.4.2.1. General

The test shall be carried out in accordance with [paragraphs 2.4.2.4. to 2.4.2.11. of this annex], (see Figure A3/9 and Figure A3/8). ~~The test shall be stopped immediately if warning indicator(s) with regard to the batteries turns on.~~

Breaks for the driver are permitted according to the regional regulations if available. If no regulation for HDVs dynamometer testing are in place, [breaks for the driver are permitted as prescribed here below for transient speed test or shortened test and in Table A3/x] for constant speed.

For transient speed, unless otherwise specified, the vehicle is allowed to stop once every [4] test cycles, the time should not exceed 10 minutes. During the stop the vehicle shall be in the "OFF" state, the test fan shall be turned-off, the brake pedal shall be released, and the battery cannot be charged using an external power source.

In the case that the test is performed using the shortened test method the breaks for the driver and/or operator are permitted only in the constant speed segments.

Table A3/x

[Break for the driver: for constant speed test

Distance driven in constant speed (km)	*Maximum total break (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 powertrain shall be switched off.]

[The following operational metrics, if present [and required], shall be monitored and recorded throughout the test: (a) battery temperature (minimum, maximum, as indicated by temperature of battery cells, modules, or pack, as available), (b) battery state of charge (from BMS and dashboard), (c) battery cooling on/off, as available. The manufacturer shall specify the normal operating range for each operational metric [in case the operational metrics monitoring is applied].]

2.4.2.2. Preparation of vehicle

The vehicle shall be presented in good technical condition and shall be run-in in accordance with the manufacturer's recommendations.

HD-PEVs and HD-OVC-HEVs shall have been run-in at least [300 km] or one full charge distance, whichever is longer.

2.4.2.3. Preparation of measurement devices

The measurement devices shall be installed at suitable and safe position(s) within the vehicle. The manufacturer shall recommend the measurement points with the approval of the responsible authority and with appropriate technical justification.

2.4.2.4. Initial setting of the battery

For HD-PEVs and HD-OVC-HEVs, prior to or during vehicle soak (paragraphs 2.4.2.5. and 2.4.2.6. of this annex), the battery shall be charged/discharged to an initial [state of charge (SOC), as reported by the vehicle,] equal or less than 10 per cent as declared by the manufacturer. At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may specify a different initial SOC of the battery.

The battery shall be charged/discharged to the initial SOC in accordance with the procedure specified by the manufacturer for normal operation until the charging process is normally terminated.

The SOC shall be confirmed by a method provided by the manufacturer.

2.4.2.5. Vehicle installation and pre-conditioning

[The vehicle and the charging station shall be installed for the preconditioning, if the battery discharge will be performed by driving in a test room.]

The battery of the vehicle shall be discharged, left stabilised for a minimum of 30 minutes and maximum 1h ~~stabilisation~~ and then fully charged at normal charge before starting the test as specified in Figure A3/5.

The manufacturer may recommend a longer stabilisation time if necessary to ensure stabilisation of the high voltage battery.

This first battery discharge, referred to as pre-conditioning, shall be performed according to manufacturer's recommendation or given speed within the range of the characteristic regional speeds or C-rate, without requirements on the ambient temperature. The manufacturer will guarantee that the battery is as fully depleted as possible by the discharge test procedure.

The end of discharge criterion is reached when the break-off criterion is met.

[In case of HD-PEV, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance or experiences a driving power cut for 4 consecutive seconds or more. The accelerator control shall be deactivated. The vehicle shall be braked to standstill within 60 seconds.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here]

1 up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority. The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

2 up to the deactivation of the powertrain, i.e., no driving mode/traction is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3 Alternative is to introduce a voltage value]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

[In case of HD-OVC-HEVs ~~the pure electric vehicle test operation mode shall be selected.~~ The break-off criterion is reached when …

~~Or if the vehicle is discharged driving on-road~~

[the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last xx km of driving is equal to or less than xx per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \frac{UBE_{cumulative}}{total\ distance - \Delta km} \quad]$$

[If the vehicle is discharged by driving on a dynamometer, according to regional regulation a Contracting Party may optionally elect to enforce that the break-off criterion is reached when $REEC_i$, as calculated using the following equation, is less than ~~[4]or~~ [5] per cent.

$$REEC_i = \frac{|\Delta E_{REESS,i}|}{E_{cycle} \times \frac{1}{3600}}$$

where:

$REEC_i$ is the relative electric energy change of the applicable test cycle considered i of the charge-depleting test;

$\Delta E_{REESS,i}$ is the change of electric energy of all REESSs for the considered charge-depleting test cycle i calculated according to paragraph 3. of this annex, Wh;

E_{cycle} is the total cycle energy demand E in Ws, and shall be calculated by summing E_i over the corresponding cycle time between t_{start} and t_{end} according to regional regulation and the following equation:

$$E = \sum_{t_{start}}^{t_{end}} E_i$$

i is the index number for the considered applicable WLTP test cycle;

$\frac{1}{3600}$ is a conversion factor to Wh for the cycle energy demand.

t_{start} is the time at which the applicable test cycle or phase starts, s;

t_{end} is the time at which the applicable test cycle or phase ends, s;

E_i is the energy demand during time period (i-1) to (i), Ws, calculated according to regional regulations;

~~$E_i = F_i \times d_i$ if $F_i > 0$~~

~~$E_i = 0$ if $F_i \leq 0$~~

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

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

~~$$F_i = f_0 + f_1 \times \left(\frac{v_i + v_{i-1}}{2}\right) + f_2 \times \frac{(v_i + v_{i-1})^2}{4} + (1.03 \times TM) \times a_i$$~~

~~where:~~

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

~~v_i is the target velocity at time t_i, km/h;~~

~~TM is the test mass, kg;~~

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

~~f_0, f_1, f_2 are the road load coefficients for the test vehicle under consideration (TM_L, TM_Hor TM_{ind}) in N, N/km/h and in N/(km/h)² respectively.~~

~~$$d_i = \frac{(v_i + v_{i-1})}{2 \times 3.6} \times (t_i - t_{i-1})$$~~

~~where:~~

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

~~v_i is the target velocity at time t_i, km/h;~~

~~t_i is time, s.~~

~~$$a_i = \frac{v_i - v_{i-1}}{3.6 \times (t_i - t_{i-1})}$$~~

~~where:~~

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

~~v_i is the target velocity at time t_i, km/h;~~

~~t_i is time, s.~~

]

]

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

[During the discharge of the battery, the operational metrics (see paragraph 2.4.2.1. of this annex) shall be recorded if required.]

[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].

2.4.2.6. Vehicle soak and charge

The soak and charge is performed in the soak area or test room if available.

If the soak and charge is performed in a soak area or test cell the soak area temperature during soak shall be as specified in [paragraph 2.4.1.4. of this annex].

It is allowed to operate a battery internal [pre-warming] system if available, recording the energy consumption for all the soak and charge duration if the soak and charge is not performed in a soak area. External [pre-warming] systems, different from charging stations, are not allowed.

The external equipment shall be powered by an external power supply.

Measurement devices installed within the vehicle shall be warmed up as appropriate.

The measurement devices shall start collecting data.

The battery shall be fully charged at a power less than or equal to the manufacturers recommendation for normal charging. ~~The battery shall be charged at full with the highest normal charging power available according to vehicle specification [≤150kW]~~. Record the charge current and voltage and the elapsed time required to reach the fully charge battery.

The vehicle shall be soaked for a minimum of 6 hours and a maximum of 36 hours to ensure temperature stabilisation of the high voltage battery.

~~The manufacturer may recommend a specific soak and charge time within the range of [6 to 36 hours] if necessary to ensure temperature stabilisation of the high voltage battery.~~

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

[Fully charged battery status shall be reached. If the selected power charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging unplugging and plugging again the vehicle with/without waiting time between the two charges.]

[The temperature of the battery shall be checked before starting the test.

It is allowed to extend the soak and charge time to stabilise the temperature of the battery]

[If the soak and charge is performed in a soak area, the vehicle shall not receive unjustified exposure to other temperatures but if that is unavoidable this time should in any case be limited to a maximum of [10] minutes.]

[To monitor the operating metrics and perform additional conditioning as necessary is allowed to maintain the operating metrics within the normal operating temperature ranges].

2.4.2.7. Discharge test cycle

The Contracting Party shall determine the combination of the test cycle mode according to the regional regulations.

[2.4.2.8. Test method for HD-PEVs

2.4.2.8.1. The constant velocity method test

The velocity shall be determined in agreement with the local authorities.

The constant driving speed shall be related to the vehicle category and characteristic regional speeds.

During the test, the speed can be controlled manually or by cruise control system. The speed deviation shall be controlled in the scope [of ± 3] km/h.

2.4.2.8.2. The transient cycle method test

The cycle shall be determined in agreement with the local authorities and according to the regional regulations.

As term of example, referring to the Title 40 of the Code of Federal Regulation, to the China stage 3 and 4 vehicle tests for fuel consumption determination and to (EU) 2017/2400 .

Different test cycles are used according to the vehicle type.

The tolerance on the speed, time and the total deviation time of each cycle are determined according to regional regulations.

[For example, the tolerance of each point of the speed shall be [±3km/h], of the time shall be ±1s, and the total deviation time of each cycle shall not exceed [15s], as shown in Figure A3/5

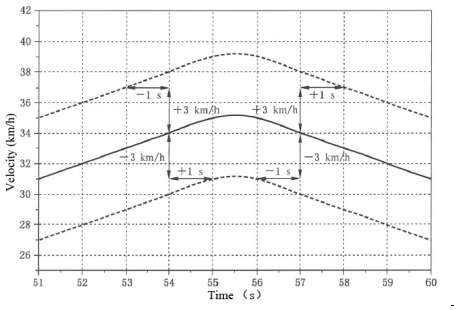


Figure A3/5 Example, reference curve and tolerance.]

2.4.2.8.3. Shortened test method

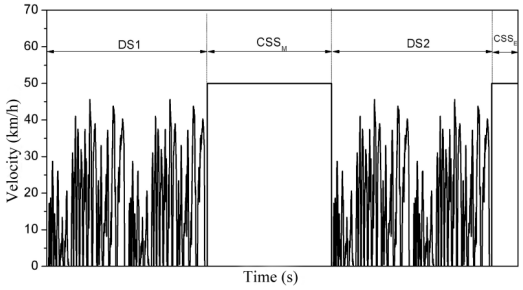


Figure A3/6 Shortened test method

The test cycle for the shortened test method is shown in Figure A3/6. The test condition consists of two test cycle segments (DS1 and DS2) and two constant speed segments (CSSM and CSSE). The constant speed section can be carried out at a higher speed to discharge faster the battery and reduce the test time. The constant speed is selected in accordance with the vehicle category and characteristic regional speeds and regional regulation.

At the request of manufacturer and with approval of the responsible authority, a higher constant speed in the constant speed segments may be selected.

The transient cycle (DS1 and DS2) and the two constant velocity segments and the length of the constant speed segments shall be defined in agreement with the local authority and regional regulation.

~~[The acceleration and deceleration during vehicle speed change shall be smooth and accomplished within the range ± [0.5-1] km/h/sec]~~

~~For the cycle segments, the tolerance requirement shall meet the requirements in Figure A3/5. For the constant velocity segments, the speed deviation shall be controlled in the scope of ± 3 km/h.~~

]

[2.4.2.8.4. Test termination for HD-PEVs

The end of discharge criterion is reached when the break-off criterion is met.

For HD-PEVs, the break-off criterion is reached when the vehicle exceeds the driving speed tolerance for 4 consecutive seconds or more or when the dashboard displays a low battery alarm, which one is occurring first. The accelerator control shall be deactivated and the vehicle shall be braked to standstill within 60 seconds after the break-off is reached.

If the HD-PEV does not experience a decrease of driving speed or a driving power cut for vehicle design, or the battery cannot be depleted on the road for safety reason, the remaining battery depletion shall be completed by on-board auxiliary systems [Note: one of the three options below will probably be selected for inclusion here]

1 up to a specific warning indicator on the vehicle dashboard to stop the discharge, defined by manufacturer for this specific purpose. The break-off criterion is reached when this warning indicator is displayed on the dashboard. The manufacturer shall provide the list of warning indicators to the responsible authority. The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

2 up to the deactivation of the powertrain, i.e., no driving mode/traction

is possible as not enough power is left to move the vehicle. The break-off criterion is reached when the deactivation of the powertrain is reached.

3 Alternative is to introduce a voltage value

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

]

[

[2.4.2.9. Test method for HD-OVC-HEVs

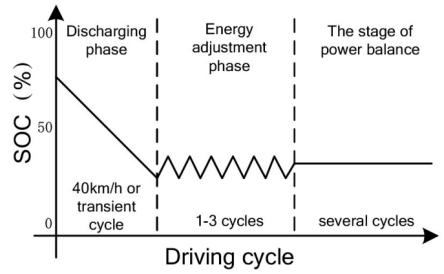


Figure A3/7 Schematic diagram of state of charge (SOC) variation of heavy-duty hybrid electric vehicle.

2.4.2.9.1. The HD-OVC-HEV has three operation stages: discharging phase, energy adjustment phase and the stage of electric power balance as depicted in figure A3/7. The UBE testing procedure shall be in phase 1 and phase 2.]

The test cycle shall be determined in agreement with the local authorities and according to the regional regulations.

[~~The conditions for determining the beginning time of the electric power balance stage can be determined according to the energy change of the battery in the test cycle . The recommended value shall be determined in agreement with the local authorities.~~

~~The test starts at fully charged battery.~~

~~The end of discharge criterion is reached when the break-off criterion is met, as described in paragraph xxx.~~

~~The HD-OVC-HEVs shall be tested applying the transient cycle method test defined in paragraph XXX [or the constant velocity method test defined in paragraph XXX.~~]

]

[2.4.2.9.2. Test termination for HD-OVC-HEVs

The end of discharge criterion is reached when the break-off criterion is met.

The break-off criterion is reached when:

- for the constant velocity method test and for the transient cycle method test,

~~the $|\Delta E_{REESS,dt}|$ $|\Delta E_{REESS,dt}|$ $|\Delta E_{REESS,dt}|$ in the last xx dt of driving is equal to or less than xx per cent of the total nominal energy capacity of the battery.~~

[the $|\Delta E_{REESS,\Delta km}|/\Delta km$ in the last xx km of driving is equal to or less than xx per cent of the cumulative UBE/(total distance travelled - Δkm) (energy consumption before the last Δkm).

$\frac{|\Delta E_{REESS,\Delta km}|}{\Delta km} \leq xx\% \frac{UBE_{cumulative}}{total\ distance - \Delta km}$].

According to regional regulation a Contracting Party may optionally elect to enforce for the transient cycle method test that the break-off criterion is reached when $REEC_i$, as calculated using the following equation, is less than ~~[4]or~~ [5] per cent.

$$REEC_i = \frac{|\Delta E_{REESS,i}|}{E_{cycle} \times \frac{1}{3600}}$$

where:

$REEC_i$ is the relative electric energy change of the applicable test cycle considered i of the charge-depleting test;

$\Delta E_{REESS,i}$ is the change of electric energy of all REESSs for the considered charge-depleting test cycle i calculated according to paragraph 3. of this annex, Wh;

E_{cycle} is the total cycle energy demand E in Ws, and shall be calculated by summing E_i over the corresponding cycle time between t_{start} and t_{end} according to regional regulations and the following equation:

$$E = \sum_{t_{start}}^{t_{end}} E_i$$

i is the index number for the considered applicable WLTP test cycle;

$\frac{1}{3600}$ is a conversion factor to Wh for the cycle energy demand.

t_{start} is the time at which the applicable test cycle or phase starts, s;

t_{end} is the time at which the applicable test cycle or phase ends, s;

E_i is the energy demand during time period (i-1) to (i), Ws, calculated according to regional regulations;

~~$E_i = F_i \times d_i$ if $F_i > 0$~~

~~$E_i = 0$ if $F_i \leq 0$~~

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

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

~~$$F_i = f_0 + f_1 \times \left(\frac{v_i + v_{i-1}}{2}\right) + f_2 \times \frac{(v_i + v_{i-1})^2}{4} + (1.03 \times TM) \times a_i$$~~

~~where:~~

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

~~v_i is the target velocity at time t_i, km/h;~~

~~TM is the test mass, kg;~~

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

~~f_0, f_1, f_2 are the road load coefficients for the test vehicle under consideration (TM_L, TM_Hor TM_{ind}) in N, N/km/h and in N/(km/h)² respectively.~~

~~$$d_i = \frac{(v_i + v_{i-1})}{2 \times 3.6} \times (t_i - t_{i-1})$$~~

~~where:~~

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

~~v_i is the target velocity at time t_i, km/h;~~

~~t_i is time, s.~~

$$a_i = \frac{v_i - v_{i-1}}{3.6 \times (t_i - t_{i-1})}$$

~~where:~~

~~a_i is the acceleration during time period (i-1) to (i), m/s^2;~~

~~v_i is the target velocity at time t_i, km/h;~~

~~t_i is time, s.~~

The manufacturer shall provide evidence to the responsible authority after the test that this requirement is fulfilled.

]

2.4.2.10. The $UBE_{~~discharge~~}$ is the total discharged energy calculated as described in [paragraph 3. of this annex].

The HD-PEV and HD-OVC-HEV shall be connected to the mains within 120 minutes after coming to a standstill, if required.

The battery shall be fully charged, if required, at a power less than or equal to the manufacturers recommendation for normal charging. ~~The REESS shall be fully charged with the highest normal charging power available according to vehicle specification ≤150kW~~The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

The end of charge criterion is reached when a fully charged battery is detected by the on-board or external instruments.

If the selected power charging does not allow to reach automatically the full charged status of the battery due to battery protection systems, it is allowed to complete the charging by applying a slower charging power unplugging and plugging again the vehicle with/without waiting time between the two charges .

[The UBE_{charge} is the total charged energy [calculated as described in paragraph 3. of this annex].]

~~[The full cycle efficiency is calculated by dividing the $UBE_{discharge}$ by the UBE_{charge}.]~~

[The Alternative Method is performed on new vehicles within a family, if applicable, to determine the $UBE_{certified}$,[~~, defined as $UBE_{discharge,cert.}$~~]]

The Alternative method is performed [on aged vehicles within a family], if applicable, to determine the $UBE_{measured}$, [~~defined as $UBE_{discharge,meas.}$~~]

The $SOCE_{measured}$ is derived according to paragraph [6.3.2. of this GTR]

2.4.2.11. End of Alternative Test Method

At the end of the Alternative test method, the measured values and the operational metrics (see paragraph 2.4.2.1. of this annex) shall be recorded.

After the measurements are complete, the vehicle and measurement devices shall be stopped.

Figure A3/8
Test sequence Alternative method

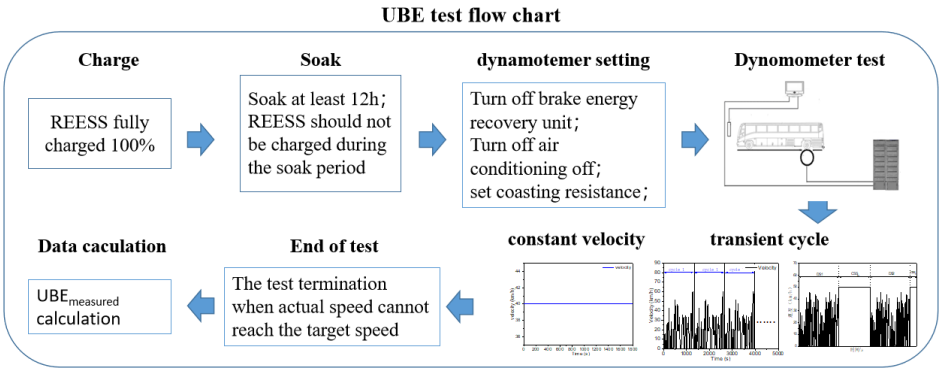
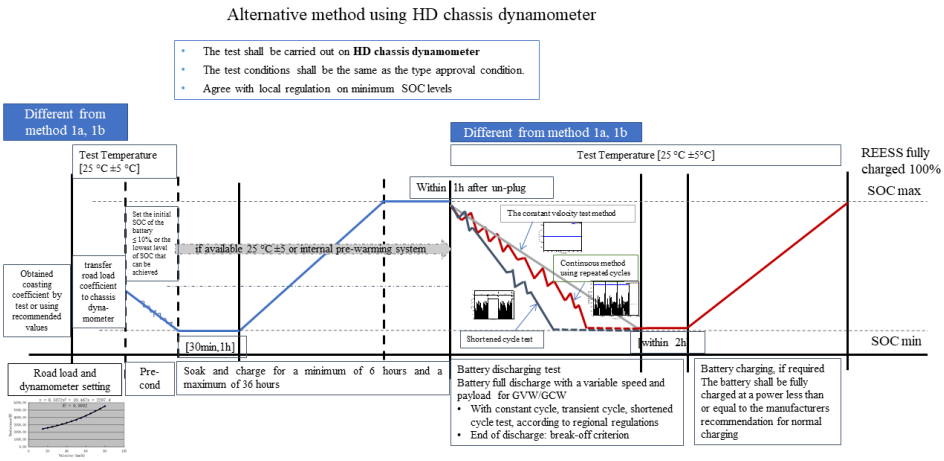


Figure A3/9
Test sequence Alternative method using HD chassis dynamometer



]

3. Performance parameters

3.1. Measured and certified UBE values

[3.1.1. Method 1a, Method 1b ~~and Alternative method HD-PEVs~~ and Method 2 for HD-PEVs and HD-OVC-HEVs and Alternative method for HD-PEVs

Parameters	Explanation
$UBE_{certified}$	$UBE_{certified}$ is the usable battery energy (UBE) of the vehicle at the point of certification.

$UBE_{measured}$	$UBE_{measured}$ is the usable battery energy (UBE) of the vehicle determined at Part A verification by the test procedure
	The required input parameter UBE is calculated as follows: $$UBE = \sum_{i=1}^{n} \Delta E_{REESS,i}$$ where: $\Delta E_{REESS,i}$ is the measured electric energy change of battery i, Wh; i is the index number of the considered battery; n is the total number of batteries; and: $$\Delta E_{REESS,i} = \frac{1}{3600} \times \int_{t_0}^{t_{end}} U(t)_{REESS,i} \times I(t)_{REESS,i}\, dt$$ where: $U(t)_{REESS,i}$ is the voltage of battery i, V; $I(t)_{REESS,i}$ is the electric current of battery i, A; t_0 is the time at the beginning of the charge or discharge test, s; t_{end} is the time at the end of the charge or discharge test (break-off criterion), s; $\frac{1}{3600}$ is the conversion factor from Ws to Wh.
No rounding shall be applied on $UBE_{measured}$. $UBE_{certified}$ shall be rounded according to [paragraph 7] of this GTR: - To the nearest whole number in case unit is Wh - To three significant numbers in case unit is kWh	

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[

3.1.2. Alternative method for HD-OVC-HEVs

Parameters	*Explanation*
$UBE_{certified}$	$UBE_{certified}$ is the usable battery energy (UBE) of the vehicle at the point of certification.
$UBE_{measured}$	$UBE_{measured}$ is the usable battery energy (UBE) of the vehicle determined at Part A verification by the test procedure
	UBE shall be the usable battery energy calculated as follows: $$UBE_{\sout{measured}} = UBE_{\sout{measured,}nc} - \Delta E_{REESS,SPB_{ave}}$$ Where: $UBE_{\sout{measured,}nc}$ is the non-corrected usable battery energy of the charge-depleting test, Wh; $\Delta E_{REESS,SPB_{ave}}$ is the average electric energy change of the stage of power balance, Wh; SPB means the stage of power balance as defined in paragraph of this annex The correction with the average electric energy change in the stage of power balance is required as the break-off criterion allows a toggling around the absolute reference level.

	The required input parameter $UBE_{\sout{measured,}nc}$ is calculated as follows: $$UBE_{\sout{measured,}nc} = \sum_{i=1}^{n} \Delta E_{REESS,i}$$ where: $\Delta E_{REESS,i}$ is the measured electric energy change of battery i, Wh; i is the index number of the considered battery; n is the total number of batteries; and: $$\Delta E_{REESS,i} = \frac{1}{3600} \times \int_{t_0}^{t_{end}} U(t)_{REESS,i} \times I(t)_{REESS,i}\, dt$$ where: $U(t)_{REESS,i}$ is the voltage of battery i, V; $I(t)_{REESS,i}$ is the electric current of battery i, A; t_0 is the time at the beginning of the charge-depleting test, s; t_{end} is the time at the end of the stage of power balance of the charge-depleting test break-off criterion, s; $\frac{1}{3600}$ is the conversion factor from Ws to Wh.
	The required input parameter $\Delta E_{REESS.SPB,ave}$ is calculated as follows: $$\Delta E_{REESS.SPB,ave} = \sum_{i=1}^{n} \Delta E_{REESS,avg,i,SPB}$$ Where: SPB is the average of the measured electric energy change of battery *i* during the stage of power balance, Wh; $i\ i\ i$ is the index number of considered battery; n is the total number of batteries; and $$\Delta E_{REESS,avg,i,SPB} = \frac{1}{3600} \times \frac{1}{t_{end,SPB} - t_{start,SPB}} \times \int_{t_{start,SPB}}^{t_{end,SPB}} \int_{t_{start,SPB}}^{t} U_{REESS,i}(t) \times I_{REESS,i}(t) dt\, dt$$ where: $U_{REESS,i}(t)$ is the voltage of battery *i*, in V $I_{REESS,i}(t)$ is the current of battery *i*, in A $t_{start,SPB}$ is the time at the beginning of the stage of power balance of the charge-depleting test, s; $t_{end,SPB}$ is the time at the end of the stage of power balance of the charge-depleting test break-off criterion, s; $\frac{1}{3600}$ is the conversion factor from Ws to Wh. SPB means the stage of power balance
No rounding shall be applied on $UBE_{measured}$. $UBE_{certified}$ shall be rounded according to [paragraph 7] of this GTR: - To the nearest whole number in case unit is Wh - To three significant numbers in case unit is kWh	

]

Annex 4 (optional annex)

[Battery Energy based (SOCE) minimum performance requirements

This optional annex includes the Minimum Performance Requirements (MPR) which a Contracting Party may optionally elect to enforce elect for conforming to the requirements of this GTR (see paragraph 5.2. of the GTR).

Table A4/1
Battery Energy based (SOCE) MPR for Category 2 vehicles not exceeding 16 tonnes

*Battery energy based MPR for **Category 2 vehicles not exceeding 16 tonnes***	*HD-OVC-HEV*	*HD-PEV*
From start of life to years or km, whichever comes first and kWh in monitoring [and additional lifetime]		
6 yr, 150 000 km	70%	70%
8 yr, 300 000 km	70%	70%
8 yr, 400 000 km	70%	70%
10 yr, 375 000 km	65%	65%

Table A4/2
Battery Energy based (SOCE) MPR for Category 2 vehicles exceeding 16 tonnes

*Battery energy based MPR for **Category 2 vehicles exceeding 16 tonnes***	*HD-OVC-HEV*	*HD-PEV*
From start of life to years or km, whichever comes first and kWh in monitoring [and additional lifetime]		
6 yr, 150 000 km	70%	70%
8 yr, 600 000 km	70%	70%
12 yr, 700 000 km	55%	55%
15 yr, 875 000 km	50%	50%

Table A4/3
Battery Energy based (SOCE) MPR for Category 1-2 vehicle not exceeding 5 tonnes

*Battery energy based MPR for **Category 1-2 vehicle not exceeding 5 tonnes***	*HD-OVC-HEV*	*HD-PEV*
From start of life to years or km, whichever comes first and kWh in monitoring [and additional lifetime]		
6 yr, 150 000 km	70%	70%
8 yr, 160 000 km		
8 yr, 300 000 km	70%	70%
10 yr, 200 000 km		

Table A4/4
Battery Energy based (SOCE) MPR for Category 1-2 vehicle exceeding 5 tonnes but not exceeding 7.5 tonnes

*Battery energy based MPR for **Category 1-2 vehicle exceeding 5 tonnes but not exceeding 7.5 tonnes***	*HD-OVC-HEV*	*HD-PEV*
From start of life to years or km, whichever comes first and kWh in monitoring [and additional lifetime]		
6 yr, 150 000 km	70%	70%
8 yr, 300 000 km		
8 yr, 500 000 km	70%	70%
10 yr, 375 000 km		

Table A4/5
Battery Energy based (SOCE) MPR for Category 1-2 vehicle exceeding 7.5 tonnes

*Battery energy based MPR for **Category 1-2 vehicle exceeding 7.5 tonnes***	*HD-OVC-HEV*	*HD-PEV*
From start of life to years or km, whichever comes first and kWh in monitoring [and additional lifetime]		
6 yr, 150 000km	70%	70%
8 yr, 600 000 km	70%	70%
12 yr, 700 000km		
15 yr, 875 000km		

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