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#### Electric Vehicles and the Environment (EVE)

UN GTRs Nos. 21 (DEVP) and

[XX] on in-vehicle battery durability

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

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

The text reproduced below 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 June 2020 to develop this UN GTR (ECE/TRANS/WP.29/AC.3/57). A first draft of this proposal was made available as an informal document by the EVE IWG at the 82nd session of GRPE (see informal document GRPE-82-27).

[Informal document addition to introductory text above](#)

An updated draft of this GTR was made available in working document GRPE-2021-18e.

At this time (i.e. the 83<sup>rd</sup> GRPE), the IWG has not reached final agreement on the necessary revisions and therefore proposes that consideration of the draft GTR by GRPE be scheduled for the next session of GRPE. This additional time is permitted under the current mandate and is needed to find agreement on the remaining technical issues.

\* In accordance with the programme of work of the Inland Transport Committee for 2021 as outlined in proposed programme budget for 2021 (A/75/6 (Sect.20), para 20.51), 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.

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

### Contents

[Editorial Note: the Table of Contents has not been updated in this Informal Document, with the one exception that a new entry has been added to recognise that a new Annex has now been proposed]

	<i>Page</i>
I. Statement of technical rationale and justification.....	3
II. Text of the GTR .....	3
1. Purpose .....	3
2. Scope and application .....	3
3. Definitions .....	3
4. Abbreviations.....	5
5. Requirements .....	5
5.1. State-of-Certified Range and State-of Certified Energy (SOCR and SOCE) monitors...	5
5.2. Battery Performance Requirements.....	6
6. In-Use Verification .....	7
6.1. Definitions of Families .....	7
6.2. Information gathering.....	8
6.3. Part A: Verification of SOCR/SOCE monitors .....	8
6.4. Part B: Verification of Battery Durability .....	12
7. Rounding .....	12
Annexes	
1. Vehicle survey.....	14
2. Monitor Flag .....	18
3. <u>Part A Test Procedure and Performance Parameter</u>	

## I. Statement of technical rationale and justification

[Editorial Note: The content of Section I is new to this Informal Document and is not amending text previously included in the GRPE-2021-18 Working Document. For ease of reading, the new content is therefore not shown here as a tracked-change – instead blue text has been used.]

### A. Introduction

1. Owing to the pressing need to reduce emissions of greenhouse gases (GHG) and other air pollutants, the market share of electrified vehicles is expected to grow in the future. A key component of these vehicles is the traction battery that is used to store and deliver energy to power the movement of the vehicle and the systems within it. Improvements in the performance of batteries to deliver increased driving range, reduced charging times and greater affordability are a significant focus for manufacturers and technological developments in this area are expected to accelerate the uptake of electrified vehicles by consumers.

2. Despite the expected improvements in the performance of new electrified vehicles, the continued in-use performance of the battery over time is not currently regulated. The primary motivation for this GTR therefore stems from the recognition that the environmental performance of electrified vehicles may be affected by excess degradation of the battery system over time.

3. Loss of electric range and loss of vehicle energy efficiency are both primary concerns. Loss of electric range could lead to a loss of utility, meaning electric vehicles are driven less and therefore displace less distance travelled that might otherwise be driven in conventional vehicles. A loss in utility could also dampen consumer sentiment and curb the market growth necessary for electric vehicle sales to deliver on fleet emissions reductions. Loss of vehicle efficiency could impact the upstream emissions by increasing the amount of electricity needed per vehicle distance travelled. Both can affect not only the utility of the vehicle to the consumer, but also the environmental performance of the vehicle. Loss of environmental performance is important, in particular because governmental regulatory compliance programs often credit electrified vehicles with a certain level of expected environmental benefit, which might not be realized over the life of the vehicle if excess battery degradation occurs.

4. In addition to changes in range and energy consumption, hybrid electric vehicles are often equipped with both a conventional and electric powertrain, and for these vehicles the criteria pollutant emissions from the conventional powertrain could be impacted by the degradation of the battery over time.

5. This GTR therefore aims to provide a harmonised methodology to address these concerns by introducing a method by which the health of the battery can be monitored over time and by setting minimum performance requirements for the durability of the battery.

### B. Procedural background

6. The Informal Working Group (IWG) on Electric Vehicle and the Environment (EVE) was set up in June 2012 following the approval by WP.29/AC.3 of ECE/TRANS/WP.29/AC.3/32. This document established two distinct IWGs to examine environmental and safety issues related to Electric Vehicles (EVs): the IWG on EVE, reporting to the Working Party on Pollution and Energy (GRPE), and the IWG on Electric Vehicle Safety (EVS), reporting to the Working Party on Passive Safety (GRSP). The proposal was supported by the European Commission, the United States of America, China, and Japan.

7. A second mandate for the IWG on EVE, divided into Parts A and B was approved in November 2014 by AC.3 to conduct additional research to address several recommendations

that grew out of the first mandate, and develop UN GTR(s), if appropriate. The second mandate was separate from the IWG on EVS.

8. Part A of the second mandate of the IWG on EVE (ECE/TRANS/WP.29/AC.3/40) included “battery performance and durability” as one of the topics authorized for study and potential GTR development. Specifically, Part A authorized activity “to further develop the recommendations for future work outlined in the Electric Vehicle Regulatory Reference Guide by: (i) conducting additional research to support the recommendations; (ii) identifying which recommendations are suitable for the development of (a) global technical regulation(s) (gtr(s)) by the World Forum for Harmonization of Vehicle Regulations (WP.29); and (iii) developing a work plan. The work of the IWG on EVE on battery performance and durability under Part A of the EVE mandate was reported to WP.29 in a status report as informal document WP.29-170-31 at the 170<sup>th</sup> meeting of WP.29, 15-18 November 2016.

9. At the close of Part A the IWG on EVE recommended that GRPE and WP.29 endorse the option of extending the mandate of the IWG on EVE to continue active research into the topic of battery performance and durability without committing to the development of a GTR at that time. This was endorsed and work continued on this topic within Part B of the mandate.

10. The IWG on EVE presented a draft status report to GRPE in May 2019 on the research on in-vehicle battery durability and performance. The status report indicated that there was sufficient information to allow a UN GTR for in-vehicle battery durability to be started. The IWG on EVE recommended at the 79th GRPE in May 2019 that the UN GTR on in-vehicle battery durability be developed under a new mandate.

11. AC.3 subsequently approved document ECE/TRANS/WP.29/AC.3/57 authorizing the IWG on EVE to develop a new UN GTR on in-vehicle battery durability which will be developed in 2 phases:

Phase 1:

(a) Deliver a first version of a UN GTR on in-vehicle battery durability to AC.3 by November 2021 with;

- (i) Definition of and requirements for electrified vehicle battery performance criteria
- (ii) Requirements for reading and/or displaying battery health information and usage data from the vehicle; and
- (iii) A provisional in-service conformity test which will include generic usage criteria and a statistical method.

Phase 2:

(b) Develop a second version of the UN GTR on in-vehicle battery durability with the following:

- (i) The development of a methodology to define Normal Usage Indices (NUI) based on data read from vehicles
- (ii) Refined performance criteria requirements for in-vehicle battery durability through assessment of further modelling and data collected from real vehicles and the use of NUIs

## C. Technical background

### Battery degradation in electrified vehicles

12. The effect of battery degradation on environmental performance is likely to differ significantly among the various electrified vehicle architectures (PEV, OVC-HEV and NOVC-HEV). The primary forms of battery degradation are capacity degradation and power degradation. Capacity degradation is the loss of energy capacity, resulting in a loss of electric driving range (for PEVs and OVC-HEVs) and possibly increased use of the engine during hybrid operation (for NOVC-HEVs). Power degradation is the loss of battery power, which

can also lead to increased use of the engine for OVC-HEV and NOVC-HEVs and possibly reduced performance of the vehicle overall.

13. There are at least five major vehicle operating conditions that affect in-vehicle battery durability. Each differs in importance depending on electrified vehicle architecture:

- (a) Discharge rates, as determined by vehicle duty cycle and operator use including, but not limited to, vehicle speed, auxiliary loads, towing, payload and ambient conditions;
- (b) Charge rates, as determined by type (normal, fast, super-fast) and frequency of charging;
- (c) State of charge (SOC) window used in system operation of the battery;
- (d) Battery temperature during operation (operation includes all temperature exposures from vehicle purchase through retirement, both while being operated and during periods of charging and inactivity); and
- (e) Time (calendar life)
- (f) Other uses, which are not reflected in calendar life, such as Vehicle to Grid (V2G).

14. The extent and nature of battery degradation that will occur is complex and heavily dependent on the battery cell chemistry and operating conditions. A variety of physical and electrochemical processes influence the durability of battery cells and these have been documented comprehensively within a literature review commissioned by the IWG on EVE. For typical lithium-ion batteries the general processes leading to capacity degradation were summarised as:

- (a) Loss or deposition of cyclable lithium or a loss of balance between electrodes;
- (b) Loss of electrode area; and
- (c) Loss of electrode material or conductivity.

15. These aging processes are often further complicated by the fact that many of the mechanisms are associated with a rise in cell impedance, leading to a reduction in maximum cell power.

#### **Management of battery degradation**

16. Whilst manufacturers have found it possible to establish the durability of specific battery implementations sufficiently to bring the products to market with some degree of confidence that normal provisions for customer satisfaction and warranty terms are being met, not every manufacturer is establishing durability in the same way. Manufacturers employ a wide variety of testing regimens often tailored to specific product configurations, applications, customer groups, and geographic considerations.

17. To reduce the effect of capacity degradation on range, manufacturers may choose to slightly oversize a PEV or OVC-HEV battery to allow for a widening of the state-of-charge (SOC) window as capacity degrades. Others may choose to design for a beginning-of-life range, and account for degradation by warranting the battery to a specified degree of capacity retention over a specified period of time. In the latter case, the consumer is expected to understand that a potential reduction in electric range is to be expected during the life of the vehicle.

18. Despite the expected loss of electric range and battery capacity retention over time, regulatory practice does not uniformly account for it. For example, US EPA range labelling rules for PEVs and OVC-HEVs effectively treat driving range as a beginning-of-life criterion, by measuring range at beginning of-life and omitting any adjustment for future capacity degradation, while still accounting for some cold temperature and high speed operation. For OVC-HEVs, however, manufacturers are indirectly compelled to account for degradation in range, in that it directly affects the calculated in-use emissions later in life. OVC-HEV greenhouse gas (GHG) emissions are calculated using the SAE J1711 procedure, which accounts for utility factor, a function of all-electric range. If range degrades during useful life, the utility factor correction would change and thus, the calculated GHG emissions would increase. Because vehicles are considered noncompliant if their emissions exceed the

certified emission level by more than 10 percent during the useful life, manufacturers that do not factor capacity degradation into their OVC-HEV designs risk exceeding the GHG standards in-use. Accordingly, for OVC-HEVs, manufacturers typically use a combination of battery oversizing and an energy management strategy that provides for a consistent range throughout the useful life.

19. A number of further measures are employed by manufacturers to limit battery degradation. These typically include, but are not limited to, the use of battery management algorithms or battery management systems (BMS). BMS can reduce stress on the battery and prolong battery life by controlling some operations to moderate the battery temperature. For example, BMS might control enhanced cooling systems, limit fast charging events through modulation of the charging current, control the available state of charge window, or reduce the maximum available torque as necessary to protect battery health. The inputs to BMS can include anything from ambient conditions and driver behaviour to individual cell metrics. Each manufacturer, vehicle, battery and cell could have unique and highly optimised BMS, that are updated and improved with every iteration. BMS are very complex and generally considered highly proprietary and should not be tampered with out of environmental and safety concerns.

#### **Estimation of battery degradation**

20. Accelerated aging is a familiar technique used by many manufacturers as a component of their battery durability testing methods. This technique assumes that a regimen of rapid aging cycles can be translated to a projected useful life in service. However, it is uncertain whether the translation from accelerated aging to an in-use life projection is equally applicable to all forms of lithium-ion chemistries either currently in use or in the future.

21. One of the major mechanisms by which capacity and power degradation occurs in these chemistries is the swelling and contraction of anode and cathode materials during cycling. Specific chemistries differ significantly in this respect, suggesting that the relation between rapid cycling and long-term cycling may also differ significantly. An accelerated test that accurately projects useful life for one chemistry may therefore predict poor life for another chemistry, even though both chemistries may achieve an equal life in actual use.

22. Furthermore, accelerated ageing cannot take into account the real use of batteries inside vehicles and therefore can only partially estimate the real degradation.

23. Most manufacturers employ some form of in situ, on-board capacity estimation through the BMS to gain an understanding on battery degradation. This estimation can vary in accuracy and precision depending on a number of factors including the sensors and estimation algorithm used, the charge/discharge behaviour of the user, the cell type and cell model parameters. Proprietary algorithms are used to handle inaccuracies and output an estimate that can be utilised by other systems within the vehicle.

24. There are currently no requirements on the accuracy of on-board monitors and the estimates generated are not typically easily accessible to the vehicle user. The IWG on EVE has therefore made a decision to set the performance requirement in this field.

## **D. Technical rationale and justification**

25. The mandate of the first phase of this GTR on in-vehicle battery durability includes the development of:

- (a) Requirements for reading and/or displaying battery health information and usage data from the vehicle;
- (b) Definition of and requirements for electrified vehicle battery performance criteria; and
- (c) A provisional in-service conformity test which will include generic usage criteria and a statistical method.

26. This section sets out the key considerations of the IWG on EVE in developing the respective elements of Phase 1 of the GTR as set out above.

**State-of-Certified Range and State-of Certified Energy (SOCR and SOCE) monitors**

27. Whilst the term State of Health (SOH) is commonly applied to refer to the health of a battery at a given point in its life, this term isn't commonly defined and is determined through a variety of different methodologies. It was therefore chosen to define two new related metrics for use within the GTR: the State of Certified Energy (SOCE) and the State of Certified Range (SOCR). Both metrics represent a percentage of the certified battery energy or electric range remaining at a given point in time. In the case of SOCE, it was decided to base the metric on the Usable Battery Energy (UBE).

28. Metrics based upon electric range and UBE were both chosen as the values can be determined through the respective certification test methodologies already applied within the contracting parties and are based on key performance parameters relating to battery health. These metrics are intended to provide both the basis of information made available to consumers and also values for assessment against Minimum Performance Requirements (MPR<sub>i</sub>) relating to battery durability by manufacturers and authorities.

29. From discussions within the IWG it was concluded that it would not be appropriate to define the process or algorithm by which the SOCR or SOCE monitors determine their estimated values. It would be highly complex to define an algorithm that could accurately account for the range of battery cell chemistry and battery management strategies in use within the market. Instead, it was determined to allow manufacturers to determine their own means to estimate these metrics, whilst ensuring the accuracy through an in-use verification procedure.

**Battery performance requirements**

30. The key battery durability requirements set out within this GTR are defined in terms of Minimum Performance Requirements (MPR<sub>i</sub>). MPR<sub>i</sub> are expressed as a minimum allowable value of SOCE or SOCR after a given length of time or distance travelled. This follows a similar format applied by manufacturers when providing warranty for electrified vehicles.

31. In determining appropriate MPR<sub>i</sub> values for this GTR the IWG on EVE considered a range of publicly available data as well as input from stakeholders within the IWG, which is summarised paragraphs 32 to 37 below.

32. Warranty analysis was conducted by the US EPA to understand the current warranty offering from manufacturers for electric vehicle batteries. The review primarily focussed on the US market, but values were also consistent with typical offerings within the European market. The review showed that batteries are covered for failure for between 7 to 10 years and between 160,000 to 1,000,000 kilometres, typically stating degradation to levels between 60 and 75 per cent. Warranty offerings of 8 years or 160,000 kilometres were found to be the most common. It has been highlighted by manufacturers that warranty offerings are not based solely on the technical performance of the battery and include further considerations from a commercial and customer satisfaction perspective. Nevertheless, the review provides an insight into the degree of confidence in products currently on the market.

33. The European Commission's Joint Research Centre (JRC) has developed a dedicated in-vehicle battery durability assessment module within its Transport Technology and Mobility Assessment (TEMA) platform. This is based on performance-based models as this class of models is the most suitable to be used with large-scale real-world driving data. TEMA is a modular big data platform designed to reproduce mobility behaviours of vehicles from datasets of navigation system data of conventional fuel vehicles and quantify possible impacts of new vehicle technologies on real-world mobility while supporting transport policy assessment.

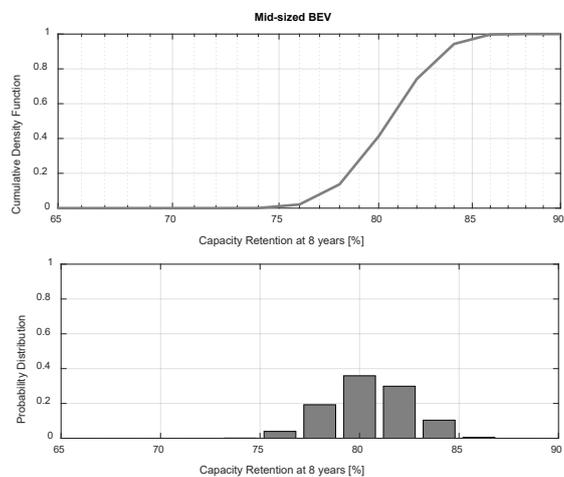
34. Recent capacity and power fade performance-based models for Lithium-ion batteries from literature have been combined with information on battery and vehicle architectures, together with real world vehicle driving data from different geographical areas of Europe, to develop a scenario-based analysis for predicting in-vehicle performance degradation of automotive traction batteries. The analysis includes the calendar and cycle capacity fade of three Lithium-ion variants (LiFePO<sub>4</sub>, NCM with spinel Mn and NCM-LMO) in different vehicle architectures (OVC-HEV and PEV of different driving range segments), combined

with different recharging strategies to explore the effect of different driving duty cycles related to different mobility patterns and environmental temperatures. Preliminary analyses on vehicle battery power fade have been also carried out.

35. The TEMA model was used to estimate the capacity retention of traction batteries after a range of distances and time periods to allow consideration of appropriate choices for MPRi. Example TEMA modelling results in Figure 1 for two different mid-sized BEVs configurations either charged with slow or fast charging show greater than 70% capacity retention after 8 years. Good agreement was previously found between TEMA modelling results and electric vehicle lifetime performance testing data provided by Canada ECCC and Transport Canada during work within the previous mandate of the IWG on EVE.

Figure 1

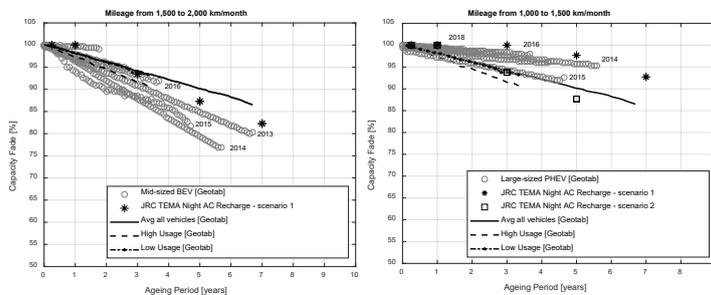
**Example of a capacity retention curve generated from JRC TEMA modelling for two different BEV configurations**



36. Geotab provides a source of publicly available information on the average battery degradation for different makes and model years of BEVs and PHEVs. The data is sourced from telematics from 6,300 fleet and consumer vehicles, covering 21 vehicle models and representing 64 distinct combinations of makes, models and years. The data also provides some insight into high vehicle use, extreme climates and charging methods. Data from Geotab was examined to understand the typical battery durability of existing vehicles in the fleet and also to compare with ageing predictions from the JRC's TEMA model, resulting in good correlation.

Figure 2

**Example comparison between estimated results from the TEMA model with in-use data from Geotab**



37. Further analysis of the publicly available Geotab data was conducted by Japan and the Alliance for Automotive Innovation, where available SOH data was extrapolated to time points of 5 and 8 years to understand the expected SOH. Japan's analysis indicated that 90 percent of the vehicle models within the sample were able to achieve approximately 80 percent SOH after 5 years and 70 percent after 8 years. The Alliance for Automotive Innovation conducted similar analysis, but also included probability estimates which indicated that between 85 and 90 percent of the current fleet covered by the Geotab data would be able to meet an 80 percent SOH target after 5 years.

38. Following consideration of the available evidence and views of stakeholders within the IWG on EVE, two sets of MPR<sub>i</sub> values were introduced based upon two different time and distance combinations. This approach allows coverage of the wide range of different distance-based requirements needed across contracting parties and provides the option for a contracting party to optionally apply only one of the MPR<sub>i</sub> if appropriate for their market.

39. The MPR<sub>i</sub> values selected were deemed to be sufficiently achievable based on the available evidence presented within the IWG, whilst also being sufficiently stringent to achieve the goal of preventing substandard products from entering the market. Following discussion within the IWG, the same MPR<sub>i</sub> were set for OVC-HEVs and PEVs.

40. It was highlighted by manufacturers that the understanding and estimation of SOCR after a given duration of use or distance travelled currently presents an increased challenge compared to SOCE. There are many factors other than those originating from the battery leading to greater uncertainty of SOCR, including the measurement, test to test variability and precision of range retention calculations. As the majority of the evidence assessed by the IWG was also based primarily on remaining capacity or battery energy, it was decided to only monitor SOCR within Phase 1.

X. No electric range based MPR<sub>i</sub> have been selected at this point in time due to the above concerns with SOCR estimation. Inclusion of MPR<sub>i</sub> for SOCR in future has, however, been highlighted as an area of importance for a number of contracting parties. Therefore, a placeholder for these values has been included to allow inclusion within a future amendment to the GTR.

41. Electrified vehicles of category 2 are at an earlier stage of adoption within the fleets of many contracting parties and subsequently in-use data relating to battery durability is scarce for these vehicles. For this reason, it is difficult presently to determine a suitable and achievable MPR<sub>i</sub> for category 2 vehicles. It has been raised by manufacturers that in future the batteries of these vehicles may also be used for supplementary purposes, in addition to propulsion, which could have further impacts on battery durability that are not currently well understood. MPR<sub>i</sub> values for category 2 vehicles therefore remain reserved for inclusion in a future amendment to this GTR.

42. Battery longevity is a key consideration for consumers and regulating agencies, therefore there is an incentive for manufacturers to accredit batteries that perform beyond the minimum requirements of this GTR. To allow manufacturers to market or quantify the benefits of any improved battery technology they may have installed within their vehicles the

GTR also allows for a Declared Performance Requirement (DPR<sub>i</sub>) to be proposed by manufacturers, based upon a higher value of SOCE/SOCR. To ensure the accuracy of any declared values, the DPR<sub>i</sub> would be considered to act in place of the MPR<sub>i</sub> for the purposes of in-use verification. The DPR<sub>i</sub> is not intended to indicate a regulatory warranted value. Manufacturer warranties are beyond the scope of this GTR. A manufacturer may wish to warranty batteries beyond the MPR<sub>i</sub> without attaching additional warranty benefits to a DPR<sub>i</sub>.

43. The new MPR setting concept as depicted with the matrix below, figure XX, was proposed by Japan in order to let each contracting party decide its own MPR as option. The matrix exemplified the area to be defined as substandard category of MPR and the area that the MPR can be determined.

The IWG considered this proposal and decided to not adopt it during the first phase.

Figure XX

Sample of MPR Matrix



**In-use verification**

44. To ensure the accuracy of the SOCE/SOCR monitors and also ensure that MPR<sub>i</sub> are being met it was necessary to introduce a two part in-use verification process, with Part A verifying the accuracy of the monitors and Part B verifying the battery durability against MPR<sub>i</sub>.

45. Part A verification involves measurement of the UBE/electric range under the applicable test procedure and determination of a measured SOCE/SOCR by dividing by the respective values from certification. These measured values can then be compared to the on-board values from the SOCE/SOCR monitors to ensure the accuracy is within a given tolerance. For this purpose, the resolution of the on-board values from SOCE/SOCR was set the 1 part in 100.

46. A pass or fail decision on a sample of vehicles will be reached through a statistical process [information on the rationale for choice of statistical procedure to be included once a decision reached within the IWG].

47. As Part A verification is expected to involve a relatively small number of sample vehicles to limit the testing burden, it is important to ensure that the sample result is not unduly impacted by the abnormal use or poor maintenance of a vehicle within the sample. A vehicle survey has therefore been introduced within Annex I containing information designed to ensure that the vehicle has been properly used and maintained according to the specifications of the manufacturer. Any vehicles not meeting the required criteria may be removed from the test sample.

48. Due to the accuracy of the SOCE/SOCR monitors being assured through verification in Part A, it is possible to verify the battery durability of a sample of vehicles within Part B through remote collection of the on-board SOCE/SOCR values, together with information on the distance travelled and age of the vehicles. This approach avoids the need for further testing of vehicles within Part B and enables a simple route to the assessment of a large sample size of vehicles, thereby minimising the impact that outliers (e.g. vehicles that have been used abnormally) may have on the sample result.

49. It is recognised that SOCE/SOCR values read from a sample of vehicles are likely to be in the form of a distribution, with values for individual vehicles dependent on the vehicle usage and any inherent variation in the performance of the vehicle or traction battery. Where a vehicle has been used abnormally (e.g. with prolonged periods of storage or being regularly used in extremes of temperature) this may also give rise to more significant degradation of battery health. To reduce the impact of vehicles that may have been used abnormally, it was decided to make the overall pass decision dependent on more than or equal to 90 per cent of monitor values read from the vehicle sample being above the  $MPR_i$ . This approach thereby ensures that the  $MPR_i$  is being met by the significant majority of the vehicle sample, whilst accounting for abnormal usage.

50. To further minimise the impact that vehicles that have been used abnormally may have on a pass or fail result within Part B when smaller sample sizes are used, the concept of a monitor flag is introduced within the GTR. This can be used to highlight those vehicles that have been used abnormally (according to Annex II) and allow them to be excluded from the dataset. [To include further information and justification on what constitutes “abnormal usage” once agreed within Annex II].

51. To support this two part in-use verification process, whilst minimising the burden of increased testing for manufacturers within Part A, two family concepts were developed within the GTR. This includes the concept of a monitor family for use in Part A and a battery durability family for Part B. This is likely to reduce the need for additional testing where multiple battery durability families may have the same characteristics with respect to verification of the SOCR/SOCE monitors.

## **E. Technical feasibility, anticipated costs and benefits**

52. The use of SOH monitoring within some electrified vehicles is already common practice and the improvement of monitor accuracy is an area under active development by manufacturers. Updating these monitors to ensure the specific requirements within this GTR are met and to allow information to be provided to the consumer may, however, entail some further development costs for manufacturers. Inclusion of SOCR for monitoring purposes only should allow manufacturers time to gather sufficient data and further develop their understanding of range deterioration to make the inclusion of range-based  $MPR_i$  technically feasible in future.

53. The Part A verification of SOCE/SOCR accuracy will involve additional testing by manufacturers and, optionally, by authorities who choose to further verify monitor accuracy. The additional costs associated with testing have been mitigated to an extent by making use of the relevant test procedure already applied for range (or UBE) determination in the respective contracting party. This should allow manufacturers to incorporate verification into any existing verification programme planned for those vehicles.

54. Any costs associated with verification within Part B are likely to be borne by the authorities of the contracting parties applying this regulation and will depend on the extent and means by which they choose to collect data for verification. Costs may be borne by the manufacturer in the case of a fail for a battery durability family relating to the costs of measures agreed with the relevant authorities to bring those vehicles back into compliance.

55. This GTR is likely to give rise to benefits for manufacturers and authorities through the prevention of inferior products which could undermine the market. Introduction of inferior products within the market could disadvantage those manufacturers who have invested in the development of technology aimed at ensuring battery longevity and could also

undermine the environmental benefits that can arise from electrified vehicles, as well as public acceptance.

56. The longevity of battery life is a key concern for prospective consumers of electrified vehicles. The health of a vehicle's battery upon entry into the second-hand market is also a significant point of consideration for the consumer and is not easily understood in the absence of access to accurate battery health monitors. The availability of both accurate battery health information and assurances on battery longevity for consumers that is provided by this GTR are therefore likely to have a positive impact on the cost retention of electric vehicles and consumer confidence in buying an electrified vehicle.

## **F. Future development of the GTR**

57. The mandate for development of this GTR included the future development of improvements to the GTR within Phase 2 that includes, but not limited to:

- (a) The development of a methodology to define Normal Usage Indices (NUIs) based on data read from vehicles; and
- (b) Refined performance criteria requirements for in-vehicle battery durability through assessment of further modelling and data collected from real vehicles and the use of NUIs.

58. The definition of NUIs was highlighted within the discussions of the IWG on EVE as a technically challenging task that will require further data collection and validation to achieve. It could, however, provide an alternative and more robust means of handling SOCE/SOCR values recorded from vehicles that have been used abnormally in future. The possibility of incorporating NUIs within this GTR should therefore be explored.

59. The implementation of this GTR by contracting parties will enable the collection of further data on SOCE and SOCR to better inform our understanding of battery health degradation. This information will, in turn, allow further refinement of the GTR, including MPR<sub>i</sub> values, based upon the latest available battery technologies employed within the market. This will be important given the rapid development of technology in the field of battery technology for electrified vehicles that is already underway.

60. The monitoring of SOCR values following the implementation of this GTR will provide a sound basis for the consideration of appropriate range-based MPR<sub>i</sub> in a future revision to this GTR. Equally, the monitoring of both SOCE and SOCR for category 2 vehicles should allow the inclusion of MPR<sub>i</sub> for this category of vehicle in future.

## II. Text of the GTR

### 1. Purpose

This Global Technical Regulation provides a worldwide harmonized method to set and verify minimum performance requirement on in-vehicle battery durability of Pure Electric Vehicles (PEVs) and Off-vehicle Charging Hybrid Electric Vehicles (OVC-HEVs).

### 2. Scope and application

This UN GTR applies to PEV and OVC-HEV vehicles of categories 1-2 and 2, both having a technically permissible maximum laden mass not exceeding 3,855 kg, and to all vehicles of category 1-1.

At the option of the Contracting Party, the scope may be limited to 3,500 kg for the relevant categories.

While manufacturers commonly estimate or publicise other range-based metrics for informational purposes (such as, for example, an in-use range under real driving conditions, or the remaining range available before the next charging event), the range-related provisions of this GTR are concerned only with the certified range as would be measured by the applicable certification test procedure.

The authorities shall take a decision for what concerns the application of this GTR to Small Volume Manufacturers.

### 3. Definitions

The following definitions shall apply in this Global Technical Regulation.

[3.x. "Battery" means a rechargeable electrical energy storage system (REESS) installed in an electrified vehicle [and used mainly for traction purposes](#).

3.x. "Usable Battery energy (UBE)" means the energy supplied by the battery from the beginning of the test procedure used for certification until the applicable break-off criterion of the test procedure used for certification is reached. For PEVs, UBE is defined in the certification test procedure by the Contracting Party. ~~For OVC-HEVs, UBE is not defined in the certification test procedure of the Contracting Parties but shall be determined as follows:~~

$$UBE_{OVC-HEV} = \sum_{j=1}^{n+1} \Delta E_{REESS,j}$$

~~$\Delta E_{REESS,j}$  is the electric energy change of all REESSs~~

~~$j$  is the index number of the applicable test cycle according to the certification test procedure of the Contracting Party~~

~~$n+1$  is the number of cycles from the beginning of the test procedure until the confirmation cycle or the charge-balanced cycle, as defined by the Contracting Party, is reached. In the confirmation cycle or charge-balanced cycle, the energy balance shall be considered and corrected to a charging balance neutral energy balance.~~

3.x. "Certified usable battery energy" refers to the UBE that was determined during the certification of the vehicle.

3.x. "Measured usable battery energy" means the UBE determined at the present point in the lifetime of the vehicle by the test procedure used for certification.

3.x. "Electric Range" refers to the range that would be determined by the range test procedure used for certification of the vehicle, if the test was performed at the present point in the lifetime of the vehicle and with the originally installed battery.

For pure electric vehicles (PEVs), the applicable range is the electric range as defined in the certification procedure by the Contracting Parties, e.g. PER as defined in UN GTR No. 15 or AER as defined in US regulations.

~~For OVC-HEVs, the applicable range is the equivalent all-electric range (EAER) calculated as follows (shown by a generic calculation scheme):~~

$$EAER = \left( \frac{A - B}{A} \right) \times C$$

Where:

~~A~~ is the charge-sustaining CO<sub>2</sub> mass emission of the Charge-Sustaining Test (called CS-test in UN GTR No. 15 and CST in US regulation)

~~B~~ is the arithmetic average of the charge-depleting CO<sub>2</sub> mass emissions of all driven cycles in the Charge-Depleting Test (CD-Test as defined in UN GTR No. 15) or in the Full Charge Test (FCT as defined in the US regulation)

~~C~~ is the distance from the beginning of the Charge-Depleting Test or Full Charge Test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criterion, including the transition cycle where the vehicle may have operated in both depleting and sustaining conditions.

3.x. "Certified range" refers to the electric driving range that was determined during certification of the vehicle.

3.x. "Measured range" means the electric range determined at the present point in the lifetime of the vehicle by the test procedure used for certification.

3.x. "Rechargeable electrical energy storage system" (REESS) means a propulsion energy storage system that stores electrical energy and which is rechargeable. A battery whose primary use is to supply power for starting the engine and/or lighting and/or other vehicle auxiliaries systems is not considered as a REESS for the purposes of this GTR. The REESS may include the necessary ancillary systems for physical support, thermal management, electronic controls and casing.

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

3.x. "State of certified range" (SOCR) means the measured or estimated on-board electric range at a specific point in its lifetime, expressed as a percentage of the certified range.

3.x. "Minimum Performance Requirement" (MPR) means the minimum durability performance, in terms of SOCE or SOCR at a specific point in the life of the vehicle, that constitutes compliance with the durability provisions of this GTR.

3.x. "Declared Performance Requirement" (DPR) means an SOCE or SOCR 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.x. "SOCR monitor" means an apparatus installed in the vehicle that maintains an estimate of the state of certified range by means of an algorithm operating on data collected from the vehicle systems.
- 3.x. "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.x. "[EstimatedOn-board](#) SOCR" means an estimate of state of certified range produced by an SOCR monitor.
- 3.x. "[EstimatedOn-board](#) SOCE" means an estimate of state of certified energy produced by an SOCE monitor.
- 3.x. "Measured SOCR" means the state of certified range as determined by the measured range divided by the certified range.
- 3.x. "Measured SOCE" means the state of certified energy as determined by the measured usable battery energy divided by the certified usable battery energy.
- to be completed, including the numbering and ordering of definitions by category.]

#### 4. Abbreviations

[SOCE	State of Certified Energy
SOCR	State of Certified Range
To be completed]	

#### 5. Requirements

- 5.1. State-of-Certified Range and State-of Certified Energy (SOCR and SOCE) monitors

The manufacturer shall install SOCR and SOCE monitors that operate during the life of the vehicle. The SOCR monitor shall maintain an estimate of the state of certified range ([estimatedon-board](#) SOCR), and the SOCE monitor shall maintain an estimate of the state of certified energy ([estimatedon-board](#) SOCE).

The manufacturer shall determine the algorithms by which [estimatedon-board](#) SOCR and [estimatedon-board](#) SOCE are determined for the vehicles they produce. The manufacturer shall update the [estimatedon-board](#) SOCR and SOCE with sufficient frequency as to maintain the necessary degree of accuracy during all normal vehicle operation. As defined in Annex 2, in cases when the monitor would not have appropriate data to produce an accurate value or when the vehicle was abnormally used, the monitor shall distinguish these cases and put a flag on the values read.

The [estimatedon-board](#) SOCR and SOCE shall [have a resolution of 1 part in 100 and be reported as the nearest whole number from 0 to 100](#)~~be rounded to the [nearest whole number/first decimal place] according to paragraph 7 of this GTR.~~

The manufacturer shall make available the most recently determined values of the [estimatedon-board](#) SOCR and [estimatedon-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 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<sub>i</sub>), which represent minimum allowable values for SOCE and SOCR at specific points in the lifetime of the vehicle. Vehicles falling under the categories of OVC-HEVs and PEVs shall meet both of the Minimum Performance Requirements in Tables 1 and 2 below. The MPRs may differ depending on the category of the vehicle and propulsion.

In order to address regional considerations, a Contracting Party may optionally elect to enforce only one of the two Minimum Performance Requirements (MPR<sub>i</sub>) in each of the tables below (i.e. either the one ending at 5 years or 100,000 km, or the one ending at 8 years or 160,000 km). ~~In the second case, the values shall apply from the start of the life of a vehicle up to 8 years or 160,000 km, whichever comes first.~~

Table 1  
Battery Energy based (SOCE) MPR

<i>Vehicle age/km for categories 1-1 and 1-2 in the scope of this GTR</i>	<i>OVC-HEV</i>	<i>PEV</i>
From start of life to 5 years or 100,000 km, whichever comes first	{80%}	{80%}
Vehicles more than 5 years or 100,000 km, and up to whichever comes first of 8 years or 160,000 km	{70%}	{70%}
<i>Vehicle age/km for category 2 in the scope of this GTR</i>		
From start of life to 5 years or 100,000 km, whichever comes first	{reserved}	{reserved}
Vehicles more than 5 years or 100,000 km, and up to whichever comes first of 8 years or 160,000 km	{reserved}	{reserved}

Table 2  
Range based (SOCR) MPR

<i>Vehicle age/km for categories 1-1 and 1-2 in the scope of this GTR</i>	<i>OVC-HEV</i>	<i>PEV</i>
From start of life to 5 years or 100,000 km, whichever comes first	{reserved}	{reserved}
Vehicles more than 5 years or 100,000 km, and up to whichever comes first of 8 years or 160,000 km	{reserved}	{reserved}
<i>Vehicle age/km for category 2 in the scope of this GTR</i>		

<i>Vehicle age/km for category 2 in the scope of this GTR</i>	<i>OVC-HEV</i>	<i>PEV</i>
From start of life to 5 years or 100,000 km, whichever comes first	{reserved}	{reserved}
Vehicles more than 5 years or 100,000 km, and up to whichever comes first of 8 years or 160,000 km	{reserved}	{reserved}

SOCR and SOCE monitors of vehicles of category 2 and SOCR monitors of category 1-1 and 1-2 vehicles shall be monitored in view of setting the values in the tables in a future amendment of this GTR.

A manufacturer may elect to declare a Declared Performance Requirement (DPRi) having an SOCE and/or SOCR value that is higher than that of the corresponding MPR. The DPRi will then replace the MPRi for the purposes of determining compliance by that manufacturer.

The manufacturer shall ensure that batteries installed in vehicles ~~will perform equal or better than~~ comply with the rules specified in paragraph 6.4.2 for the MPRi (or DPRi if applicable).

## 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 into vehicle families for the purpose of compliance verification. Families under Part A shall have the same characteristics with respect to verification of the SOCR/SOCE monitors. Families under Part B shall have the same characteristics with respect to verification of battery durability. ~~[and shall be subsets of Part A families].~~ Families with the same characteristics for what regards compliance verification shall be defined as follows:

#### 6.1.1. For Part A: Verification of Monitors

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

- ~~{~~(a) Algorithm for estimating SOCR and SOCE ~~whether included or not in the Battery Management System~~, and for determining flag conditions described in Annex 2, ~~including software version~~\*
- (b) Sensor configuration (for sensors used in determination of SOCR and SOCE estimates and flag conditions)
- (c) ~~Characteristics of battery cell which have a non-negligible influence on accuracy of monitor~~Type and dimension of cell (including format and chemistry)
- (d) ~~Battery management system (BMS)\* (with regards to battery durability monitoring and estimations)~~
- (e) Type of vehicle (PEVs or 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.~~

~~At the request of the manufacturer and the approval of the responsible authority the monitor family may be extended in the case of a different algorithm or~~

~~BMS if there is sufficient evidence that the performance of the monitor will not be affected.~~

6.1.2. For Part B: Verification of Battery Durability

Only vehicles that are ~~identical~~ substantially similar with respect to the following ~~elements electric powertrain/transmission characteristics~~ may be part of the same battery durability family:

- ~~(a)~~ Type and number of electric machines, including: net power; construction type (asynchronous/ synchronous, etc.), ~~type of coolant (air, liquid), method of cooling~~ and any other characteristics having a non-negligible influence on battery durability;
- (b) Type of traction REESS (dimensions, type of cell, including format and chemistry, capacity (Ampere-hour), nominal voltage, nominal power; ~~type of coolant (air, liquid)~~);
- (c) Battery management system (BMS) (with regards to battery durability monitoring and estimations);
- (d) ~~Insulation/packaging of the battery~~ Passive and active thermal management of the battery;
- ~~(e) Transmission type (e.g. manual, automatic, CVT) and transmission model (e.g. torque rating, number of gears, numbers of clutches, etc.);~~
- ~~(f) Number of powered axles;~~
- (g) Type of electric energy converter between the electric machine and traction REESS, between the recharge-plug-in and traction REESS, and any other characteristics having a non-negligible influence on battery durability;
- (h) Operation strategy of all components influencing the battery durability;
- ~~(ig) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the n/v ratios of the most commonly installed transmission type and model is within 8 per cent.~~
- (hg) Declared maximum charging power.

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, ~~with appropriate technical justification~~.

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 paragraph 5.2 after the last vehicle of this family is sold.

6.3. Part A: Verification of SOCR/SOCE monitors

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 authorities, until 5 or 8 years as defined in paragraph 5.2. 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.

~~[The At the option of the Contracting Party, the verification of the monitors shall not be mandatory if the annual sales of the monitor family are less than 5,000 vehicles in the market for the previous year. Such in-service conformity 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 SOCR/SOCE monitors, the values for range and battery usable energy shall be measured at the time of the verification and the related values from the monitors read. In cases where the either monitor is reporting a flag for not being able to monitor accurately according to Annex 2, Cases A, then these vehicles shall be corrected, according to the instructions of the manufacturer, until the flag disappears and then tested. The manufacturer shall provide instructions on what is required to make the monitor able to provide an accurate value.

The measured SOCR and measured SOCE values shall be determined by dividing the measured values for range and usable battery energy by the certified values for range and usable battery energy, respectively ~~and rounded to the nearest [whole number/first decimal place] according to paragraph 7 of this GTR~~, expressed in %.

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

$$SOCR_{measured} = \frac{Range_{measured}}{Range_{~~estimated~~certified}} * 100$$

~~In cases where  $UBE_{measured}$  is higher than the  $UBE_{certified}$ , the  $SOCE_{measured}$  shall be set to 100%. In cases where  $Range_{measured}$  is higher than the  $Range_{certified}$ , the  $SOCR_{measured}$  shall be set to 100%.~~

### 6.3.3. ~~Pass/Fail decision for a vehicle test~~

#### 6.3.3.1. ~~Pass decision~~

~~A vehicle test shall be considered a pass (p) when the estimated on-board SOCR and estimated on-board SOCE read from the vehicle are both not more than 5 percentage points greater than the respective measured value.~~

#### 6.3.3.2. ~~Fail decision~~

~~A vehicle test shall be considered a fail (f) when either the estimated on-board SOCR or the estimated on-board SOCE read from the vehicle are more than 5 percentage points greater than the respective measured value.~~

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

Separate statistics shall be calculated for the SOCR monitor and the SOCE monitor.

~~An adequate number of vehicles shall be selected from the same monitor family for testing following a vehicle survey (see Annex 1) containing 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.~~

~~[To be defined as one from the following options:~~

~~Option A: 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 SOCR/SOCE 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 Figure 1. The charts indicate 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 Figure 1 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 Figure 1 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.

Option A1:

Figure 1

**Decision chart for the statistical procedure (where 'UND' means undecided)**

	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	FAIL
9	-	-	-	-	-	-	FAIL	FAIL
8	-	-	-	-	-	FAIL	FAIL	FAIL
7	-	-	-	-	FAIL	FAIL	FAIL	FAIL
6	-	-	-	FAIL	FAIL	FAIL	FAIL	FAIL
5	-	-	FAIL	FAIL	FAIL	UND	UND	PASS
4	-	FAIL	FAIL	UND	UND	UND	UND	PASS
3	FAIL	FAIL	UND	UND	UND	UND	PASS	PASS
2	UND	UND	UND	UND	PASS	PASS	PASS	PASS
1	UND	PASS						
0	PASS							
	-	-	-	-	-	-	-	-
	3	4	5	6	7	8	9	10

Option A2: Another possibility is the table from UN Regulation No. 83, 07 series of amendments, which is based on International Standard ISO 8422:1991. See Table 3.

Table 3

Table for acceptance/rejection sampling plan by attributes

Cumulative sample size (n)	Pass decision number	Fail decision number
3	0	-
4	1	-
5	1	5
6	2	6
7	2	6
8	3	7
9	4	8
10	4	8
11	5	9
12	5	9
13	6	10
14	6	11
15	7	11
16	8	12
17	8	12
18	9	13
19	9	13
20	11	12

Option B:

#### Part A: Verification of SOCR/SOCE monitors

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) containing 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 SOCR/SOCE monitors normalised values shall be calculated:

$$x_i = \frac{SOC_{read,i}}{SOC_{measured,i}} x_i = SOC_{read,i} - SOC_{measured,i}$$

Where

$SOC_{read,i}$  is the SOCR/SOCE monitor read from the vehicle  $i$ ; and

$SOC_{measured,i}$  is the measured SOCR/SOCE monitor of the vehicle  $i$ .

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

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

and

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

For each number of tests  $3 \leq N \leq 16$ , one of the three following decisions can be reached, where the factor A shall be set at [4.0+5]:

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

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

(c) Take another measurement if:

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

where the parameters  $t_{P1,N}$ ,  $t_{P2,N}$ ,  $t_{F1,N}$ , and  $t_{F2}$  are taken from Table 4.

Table 4  
Pass/fail decision number for the sample size

Tests (N)	PASS		FAIL	
	$t_{P1,N}$	$t_{P2,N}$	$t_{F1,N}$	$t_{F2}$
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

#### 6.3.5. Corrective measures for the SOCR and SOCE monitors

A fail decision for the sample means that the monitors fail 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 brings all vehicles in the same monitor family in conformity by repairing or replacing the faulty monitor including the relevant sensors or by applying software measures in all affected vehicles in the monitor family.

A pass decision or correction of the non-conformity 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 authorities from a statistically adequate sample of vehicles within the same battery durability family. The decision on the number of the 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, a maximum of 5% of the values might be excluded from the sample.

For vehicles with extended V2X usage, the following provisions shall apply to all vehicles: tbc

presence of a flag of the monitor triggered by Cases B of Annex 2 shall be used to decide whether the vehicle has been abnormally used and therefore should be excluded from the sample.

All vehicles with a flag of the monitor according to Annex 2, Cases A shall be excluded from the sample;

The data read shall be those of the SOCR and SOCE monitors (and other relevant data, such as the flags according to Annex 2). SOCR and SOCE monitors of vehicles of category 2 and SOCR monitors of category 1-1 and 1-2 vehicles shall be monitored.

#### 6.4.2. Pass/Fail Criteria for the battery durability family

A battery durability family shall pass if equal or more than {90 per cent} of monitor values read from the vehicle sample are above the MPRi or DPRi.

A battery durability family shall fail if less than {90 per cent} of monitor values read from the vehicle sample are below the MPRi or DPRi.

The percentage from the vehicle sample shall be rounded to the [nearest whole number/first decimal place] according to paragraph 7 of this GTR.

#### 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 in conformity.

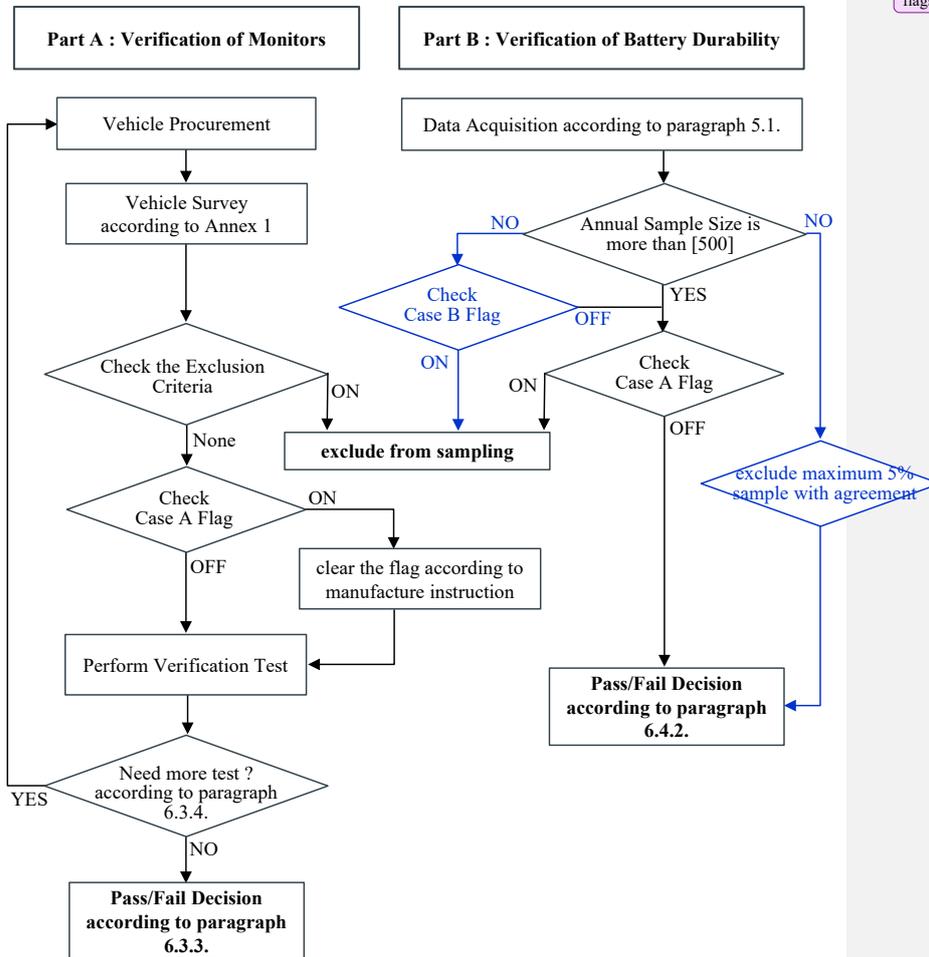
#### 6.5 Process graph

The graph below illustrates the various steps in the verification process.

**Commented [DP(1)]:** To evaluate whether this is a simple solution to remove cases B.

**Commented [DP(2)]:** Japan proposes to keep flag A also for Part B evaluation. But take away Flag B.

Commented [DP(3)]: To refine after decisions are taken on the flags.



## 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 1.234 grams but only two places of decimal are to be retained, the final result shall be 1.23 grams.

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 1.236 grams but only two places of decimal are to be retained, and because 6 is greater than 5, the final result shall be 1.24 grams.

## Annex 1

## Vehicle Survey

The vehicle survey shall be used for all vehicles selected for testing in Part A of the verification.

	x = Exclusion Criteria	x = Checked and reported	Confidential
<b>Date:</b>			x
<b>Name of investigator:</b>			x
<b>Location of test:</b>			x
<b>Country of registration:</b>		x	

Vehicle Characteristics	x = Exclusion Criteria	x = Checked and reported	Confidential
<b>Registration plate number:</b>		x	x
<b>Mileage:</b> <i>The vehicle must have mileage and age (defined as the time elapsed after first registration) below the one required in Section 5.2 for the MPR verification</i>	x		
Is the vehicle either PHEV or BEV?	x		
<b>Date of first registration:</b>		x	

<b>VIN:</b>		x	
<b>Emission class and character or Model Year</b>		x	
<b>Country of registration:</b> <i>The vehicle must be registered in a CP</i>	x	x	
<b>Model:</b>		x	
<b>Engine code:</b>		x	
<b>Engine volume (l):</b>		x	
<b>Engine power (kW):</b>		x	
<b>Electric Engine code:</b>		x	
<b>Electric Engine power (kW):</b>		x	
<b>Electric powertrain type</b>		x	
<b>Energy capacity and type of battery</b>		x	
<b>Gearbox type (auto/manual):</b>		x	
<b>Drive axle (FWD/AWD/RWD):</b>		x	
<b>Tyre size (front and rear if different):</b>		x	
<b>Average fuel consumption for PHEVs</b>		x	
<b>Is the vehicle involved in a recall or service campaign?</b> <b>If yes: Which one? Have the campaign repairs already been done?</b> <i>The repairs must have been done before selecting the vehicle.</i>	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)

<b>Name of the owner (only available to the accredited inspection body or laboratory/technical service)</b>			x
<b>Contact (address / telephone) (only available to the accredited inspection body or laboratory/technical service)</b>			x
<b>How many owners did the vehicle have?</b>		x	
<b>Did the odometer work?</b> <i>If no, the vehicle cannot be selected.</i>	x		
<b>Was the vehicle used for one of the following?</b>			
As car used in show-rooms?		x	
As a taxi?		x	
As a delivery vehicle?		x	
For racing / motor sports?	x		
As a rental car?		x	
<b>Has the vehicle carried heavy loads over the specifications of the manufacturer?</b> <i>If yes, the vehicle cannot be selected.</i>	x		
<b>Have there been major engine, electric motor or vehicle repairs?</b>		x	
<b>Have there been unauthorised major engine or vehicle repairs?</b> <i>If yes, the vehicle cannot be selected.</i>	x		
<b>Was the propulsion battery changed or repaired?</b> <i>If yes the vehicle cannot be selected for testing, but information should be collected</i>	x		x
<b>Has there been an unauthorised power increase/tuning?</b> <i>If yes, the vehicle cannot be selected.</i>	x		
<b>Was any part of the emissions after-treatment system modified?</b> <i>If yes, the vehicle cannot be selected</i>	x		
<b>Where do you use your vehicle more often?</b>			
% motorway	-	-	-
% rural	-	x	-
% urban	-	x	-
<b>Has the vehicle been maintained and used in accordance with the manufacturer's instructions?</b> <i>If not, the vehicle cannot be selected.</i>	x		
<b>Full service and repair history including any re-works</b> <i>If the full documentation cannot be provided, the vehicle cannot be selected.</i>	x		
<b>Battery related checks: (Indicating Normal Use)</b>			
<b>How often did you charge the vehicle when:</b>			
%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 superfast 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	
[What percentage of time was the vehicle used for V2G or other similar non-propulsion purposes, including but not limited to home back-up, charging another vehicle, or for grid services?]		x	
Was the vehicle stored and not used for more than one full month during its life? If so, how many times per year?		x	

Commented [EVE45IWG4]: Same as Annex II, case B. Could delete.

x=  
Exclusion Criteria    x=checked and reported    Relevant for BEV

Vehicle Examination and Maintenance (please use the relevant entries according to the type of vehicle)

<b>Fuel tank level (full / empty)</b> Is the fuel reserve light ON? <i>If yes, refuel before test.</i>		x	
<b>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?)</b> <i>If yes, the vehicle cannot be selected</i>	x		
<b>Is the SCR light on after engine-on?</b> <i>If yes, the reagent should be filled, or the repair executed before the vehicle is used for testing.</i>	x		
<b>Visual inspection exhaust system</b> Check leaks between exhaust manifold and end of tailpipe. Check and document (with photos) <i>If there is damage or leaks, the vehicle cannot be tested</i>	x		
<b>Exhaust gas relevant components</b> Check and document (with photos) all emissions relevant components for damage. <i>If there is damage, the vehicle cannot be tested</i>	x		
<b>Air filter and oil filter</b> Check for contamination and damage. Change if damaged or heavily contaminated or less than 800 km before the next recommended change.		x	
<b>Wheels (front &amp; rear)</b> Check whether the wheels are freely moveable or blocked or impeded by the brake. <i>If not freely moveable, the vehicle cannot be selected.</i>	x		Y
<b>Drive belts &amp; cooler cover</b> <i>In case of damage, the vehicle cannot be tested.</i>	x		
<b>Check fluid levels</b> Check the max. and min. levels (engine oil, cooling liquid) / top up if below minimum		x	
<b>Vacuum hoses and electrical wiring</b> Check all for integrity. <i>In case of damage, the vehicle cannot be tested.</i>	x		Y

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

Remarks for: Repair / replacement of components / part numbers

## [Annex 2

### Monitor Flag

Cases where the monitor will raise a flag, since it will not be able to produce an accurate value or the vehicle has been used abnormally:

#### Cases A: where the monitor does not have enough data to produce an accurate value:

1. The vehicle has not done a full charge-discharge cycle during the last month
2. [The monitor has not been updated in the last \[1 month\]](#)

#### Cases B: where the vehicle was used “abnormally”:

1. ~~The vehicle was stored (not connected) and not used for a full month on more than 3 occasions per year.~~
2. ~~The vehicle was used more than 20 per cent of the time in conditions below -7 C or more than 35 C.~~
3. ~~The vehicle was charged with superfast chargers more than 50 per cent of the time.~~
4. ~~There was significant V2G or other usage of the battery that would not be shown by miles driven.~~
5. ~~There is evidence the battery system has been tampered with or altered in a manner not approved by the manufacturer.~~

To be completed]

**[Annex 3**

**Part A Test Procedure and Performance Parameter**

1. \_\_\_\_\_ in case of WLTP (GTR#15)

1.1. \_\_\_\_\_ PEV

The usable battery energy and pure electric range shall be calculated according to GTR#15 Amd#6 Annex 8 paragraph 4.4.2.1.1. in case of the shortened Type I test procedure or paragraph 4.4.2.2.1. in case of the consecutive cycle Type I test procedure **modifying** the following stepwise procedure

parameters	Shorten Test Procedure	Consecutive Cycle Procedure
UBE <sub>measured</sub>	Table A8/11 Step no.1 <u>UBE<sub>measured</sub> shall be rounded according to paragraph 7. of UN GTR#15 to the nearest whole number.</u>	Table A8/10 Step no.1 <u>UBE<sub>measured</sub> shall be rounded according to paragraph 7. of UN GTR#15 to the nearest whole number.</u>
UBE <sub>certified</sub>	Table A8/11 Step no.6 <u>Averaging of tests for UBE<sub>STP,ave</sub>, then alignment of UBE<sub>STP,ave</sub> by applying AF<sub>PEE</sub></u> In the case that the interpolation method is not applied, UBE <sub>CCP,ave</sub> shall be rounded according to paragraph 7. to the nearest whole number. Table A8/11 Step no.9 <u>Select the maximum UBE<sub>STP,ave</sub> and final rounding to the nearest whole number according to paragraph 7.</u>	Table A8/10 Step no.7 <u>Averaging of tests for UBE<sub>CCP,ave</sub>, then alignment of UBE<sub>CCP,ave</sub> by applying AF<sub>PEE</sub></u> In the case that the interpolation method is not applied, UBE <sub>CCP,ave</sub> shall be rounded according to paragraph 7. to the nearest whole number. Table A8/10 Step no.10 <u>Select the maximum UBE<sub>CCP,ave</sub> and final rounding to the nearest whole number according to paragraph 7.</u>
Range <sub>measured</sub>	Table A8/11 Step no.6 or 9 <u>No rounding</u>	Table A8/10 Step no.7 or 10 <u>No rounding</u>
Range <sub>certified</sub>	Table A8/11 Step no.6 or 9	Table A8/10 Step no.7 or 10

**Commented [JPN5]:** under the study depend on unit or require at least three(3) significant number ?

**Commented [JPN7]:** same as above

**Commented [JPN6]:** same as above

**Commented [JPN8]:** same as above

**Commented [JPN9]:** nearest whole number seems to be OK

1.2. \_\_\_\_\_ OVC-HEV

The usable battery energy and shall be calculated according to GTR#15 Amd#6 Annex 8 paragraph 4.3. and the equivalent all-electric range shall be calculated according to GTR#15 Amd#6 Annex 8 paragraph 4.4.4.1. **modifying** the following stepwise procedure

parameters	stepwise procedure
UBE <sub>measured</sub>	$\Delta E_{REESS,j} = \sum_{i=1}^n \Delta E_{REESS,j,i}$ $\Delta E_{REESS,j,i} = \frac{1}{3600} \times \int_{t_0}^{t_{end}} U(t)_{REESS,j,i} \times I(t)_{j,i} dt$ <p><u>t<sub>end</sub> is the time at the end of the confirmation cycle j, s; then correct to charge/discharge energy balance point</u></p> $UBE_{corr} = UBE_{meas} + (\Delta E_{REESS,end} - \Delta E_{REESS,ave})$

	<p><u>rounding to the nearest whole number according to paragraph 7. of UN GTR#15</u></p>
UBE <sub>certified</sub>	$\Delta E_{REESS,j} = \sum_{i=1}^n \Delta E_{REESS,j,i}$ $\Delta E_{REESS,j,i} = \frac{1}{3600} \times \int_{t_0}^{t_{end}} U(t)_{REESS,j,i} \times I(t)_{j,i} dt$ <p>t<sub>end</sub> is the time at the end of the transient cycle j, s;  then correct to charge/discharge energy balance point  <math>UBE_{corr} = UBE_{meas} + (\Delta E_{REESS,end} - \Delta E_{REESS,ave})</math>  <u>how to align the measured value to declared value ?</u>  <u>rounding to the nearest whole number according to paragraph 7. of UN GTR#15</u></p>
Range <sub>measured</sub>	<p>Table A8/9 Step no.3 with modifying the following calculation formula</p> $EAER = \left( \frac{M_{CO2,CS} - M_{CO2,CD,avg}}{M_{CO2,CS}} \right) \times R_{CDC}$
Range <sub>certified</sub>	<p>Table A8/9 Step no.8 or 9</p>

**Commented [JPN10]:** under the study depend on unit or require at least three(3) significant number?

**Commented [JPN11]:** under the study

**Commented [JPN12]:** Depend on unit Or require at least three(3) significant number

X. notes : other UNRs (R83/R101) and regional regulations (e.g. US CFR, others) need same kind of additional specific process, if necessary

US CFR : .....

R83 for OVC-HEV (Grid-connected hybrid electric vehicle) : .....

R101 for PEV (BEV) : .....

others : .....

1