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Item 6(d) of the provisional agenda

**AMENDMENTS TO UNECE REGULATIONS**

**REGULATION No. 101**  
**(CO<sub>2</sub> emissions/fuel consumption)**

Proposal for draft amendments to Regulation No. 101

Submitted by the expert from the United Kingdom<sup>\*/</sup>

The text reproduced below was prepared by the expert from the United Kingdom in respect of measurement procedures for Externally Chargeable Hybrid Electric Vehicles. These modifications aim at better reflecting the CO<sub>2</sub> emissions benefits of Externally Chargeable Hybrid Electric Vehicles with control strategies programmed to start the internal combustion engine early, e.g. during periods of high power demand, to preserve the external charge imparted to the battery. The modifications to the current text of Annexes 8 and 9 to the Regulation are marked in **bold** characters.

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<sup>\*/</sup> In accordance with the programme of work of the Inland Transport Committee for 2006-2010 (ECE/TRANS/166/Add.1, programme activity 02.4), the World Forum will develop, harmonize and update Regulations in order to enhance performance of vehicles with respect to pollution and energy. The present document is submitted in conformity with that mandate.

A. PROPOSAL

Insert a new paragraph 2.16., to read:

**"2.16. OVC range: the total distance covered during complete combined cycles run until the energy imparted by external charging of the battery (or other electric energy storage device) is depleted, as measured according to the procedure described in Annex 9."**

Paragraph 2.16. (former), renumber as paragraph 2.17.

Annex 4, item 7.2.2.1., amend to read:

"7.2.2.1. **Electric Range: .....km"**

Annex 4, item 7.3.10., amend to read:

**"7.3.10. OVC Range: .....km"**

Annex 8, paragraphs 3. to 4.4.6., amend to read:

"3. EXTERNALLY CHARGEABLE (OVC ELECTRIC HEV) WITHOUT AN OPERATING MODE SWITCH

3.1. Two tests shall be performed under the following conditions:

Condition A: test shall be carried out with a fully charged electrical energy/power storage device.

Condition B: test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

The profile of the state of charge (SOC) of the electrical energy/power storage device during different stages of the Type I test is given in Appendix 1.

3.2. Condition A

3.2.1. The procedure shall start with the discharge of the electrical energy/power storage device as described in paragraph 3.2.1.1. below:

3.2.1.1. Discharge of the electrical energy/power storage device

The electrical energy/power storage device of the vehicle is discharged while driving (on the test track, on a chassis dynamometer, etc.):

(a) at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up,

- (b) or, if a vehicle can not reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer),
- (c) or with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

### 3.2.2. Conditioning of the vehicle

3.2.2.1. For conditioning compression-ignition engined vehicles the Part Two cycle of the applicable driving cycle shall be used in combination with the applicable gear shifting prescriptions as defined in paragraph 1.4. of this annex. Three consecutive cycles shall be driven.

3.2.2.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two cycles of the applicable driving cycle in combination with the applicable gear shifting prescriptions as defined in paragraph 1.4. of this annex.

3.2.2.3. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within +/- 2 K of the temperature of the room, and the electrical energy/power storage device is fully charged as a result of the charging prescribed in paragraph 3.2.2.4. below.

3.2.2.4. During soak, the electrical energy/power storage device shall be charged, using the normal overnight charging procedure as defined in paragraph 3.2.2.5. below.

#### 3.2.2.5. Application of a normal overnight charge

The electrical energy/power storage device shall be charged according to the following procedure.

##### 3.2.2.5.1. Normal overnight charge procedure

The charging is carried out:

- (a) with the on board charger if fitted, or
- (b) with an external charger recommended by the manufacturer using the charging pattern prescribed for normal charging;
- (c) in an ambient temperature comprised between 20 °C and 30 °C. This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges. The manufacturer shall declare that during the test, a

special charge procedure has not occurred.

#### 3.2.2.5.2. End of charge criteria

The end of charge criteria corresponds to a charging time of 12 hours, except if a clear indication is given to the driver by the standard instrumentation that the electrical energy/power storage device is not yet fully charged.

In this case,

$$\text{the maximum time is} = \frac{3 \cdot \text{claimed battery capacity (Wh)}}{\text{mains power supply (W)}}$$

#### 3.2.3. Test procedure

3.2.3.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

**3.2.3.2. The test procedures defined in either paragraph 3.2.3.2.1. or 3.2.3.2.2. may be used.**

3.2.3.2.1. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

**3.2.3.2.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and continue over a number of repeat test cycles. It shall end on conclusion of the final idling period in the first extra-urban (Part Two) cycle during which the battery reached the minimum state of charge according to the criterion defined below (end of sampling (ES)).**

**The electricity balance Q [Ah] is measured over each combined cycle, using the procedure specified in Appendix 2 to this annex, and used to determine when the battery minimum state of charge has been reached.**

**The battery minimum state of charge is considered to have been reached in combined cycle N if the electricity balance measured during combined cycle N+1 is not more than a 3 per cent discharge, expressed as a percentage of the nominal capacity of the battery (in Ah) in its minimum state of charge, as declared by the manufacturer. At the manufacturer's request additional test cycles may be run and their results included in the calculations in paragraphs 3.2.3.5. and 3.4.1. provided that the electricity balance for each additional test cycle shows less discharge of the battery than over the previous cycle.**

**In between each of the cycles a hot soak period of up to 10 minutes is allowed. The powertrain shall be switched off during this period.**

- 3.2.3.3. The vehicle shall be driven using the applicable driving cycle and gear shifting prescriptions as defined in paragraph 1.4. to this annex.
- 3.2.3.4. The exhaust gases shall be analysed according to Annex 4 of Regulation No. 83 in force at the time of approval of the vehicle.
- 3.2.3.5. The test results on the combined cycle (CO<sub>2</sub> and fuel consumption) for Condition A shall be recorded (respectively  $m_1$  [g] and  $c_1$  [l]). **In the case of testing according to paragraph 3.2.3.2.1.,  $m_1$  and  $c_1$  are simply the results of the single combined cycle run. In the case of testing according to paragraph 3.2.3.2.2.,  $m_1$  and  $c_1$  are the sums of the results of the N combined cycles run.**

$$m_1 = \sum_1^N m_i \quad c_1 = \sum_1^N c_i$$

- 3.2.4. Within the 30 minutes after the conclusion of the **last** cycle, the electrical energy/power storage device shall be charged according to paragraph 3.2.2.5. of this annex). The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy  $e_1$  [Wh] delivered from the mains.
- 3.2.5. The electric energy consumption for condition A is  $e_1$  [Wh].
- 3.3. Condition B
- 3.3.1. Conditioning of the vehicle
- 3.3.1.1. The electrical energy/power storage device of the vehicle shall be discharged according to paragraph 3.2.1.1. of this annex. At the manufacturer's request, a conditioning according to paragraph 3.2.2.1. or 3.2.2.2. of this annex may be carried out before electrical energy / power storage discharge.
- 3.3.1.2. Before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within +/- 2 K of the temperature of the room.
- 3.3.2. Test procedure
- 3.3.2.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.
- 3.3.2.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle

(Part Two, end of sampling (ES)).

3.3.2.3. The vehicle shall be driven using the applicable driving cycle and gear shifting prescriptions as defined in paragraph 1.4. of this annex.

3.3.2.4. The exhaust gases shall be analysed according to Annex 4 of Regulation No. 83 in force at the time of approval of the vehicle.

3.3.2.5. The test results on the combined cycle (CO<sub>2</sub> and fuel consumption) for Condition B shall be recorded (respectively m<sub>2</sub> [g] and c<sub>2</sub> [l]).

3.3.3. Within the 30 minutes after the conclusion of the cycle, the electrical energy/power storage device shall be charged according to paragraph 3.2.2.5. of this annex.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e<sub>2</sub> [Wh] delivered from the mains.

3.3.4. The electrical energy/power storage device of the vehicle shall be discharged according to paragraph 3.2.1.1. of this annex.

3.3.5. Within 30 minutes after the discharge, the electrical energy/power storage device shall be charged according to paragraph 3.2.2.5. of this annex.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e<sub>3</sub> [Wh] delivered from the mains.

3.3.6. The electric energy consumption e<sub>4</sub> [Wh] for condition B is: e<sub>4</sub> = e<sub>2</sub> - e<sub>3</sub>

3.4. Test results

3.4.1. The values of CO<sub>2</sub> shall be M<sub>1</sub> = m<sub>1</sub>/D<sub>test1</sub> and M<sub>2</sub> = m<sub>2</sub>/D<sub>test2</sub> [g/km] with D<sub>test1</sub> and D<sub>test2</sub> the **total** actual driven distances in the tests performed under conditions A (paragraph 3.2. of this annex) and B (paragraph 3.3. of this annex) respectively, and m<sub>1</sub> and m<sub>2</sub> determined in paragraphs 3.2.3.5. and 3.3.2.5. of this annex respectively.

3.4.2. The weighted values of CO<sub>2</sub> shall be calculated as below:

**3.4.2.1. In the case of testing according to paragraph 3.2.3.2.1.:**

$$M = (D_e \cdot M_1 + D_{av} \cdot M_2) / (D_e + D_{av})$$

Where:

M = mass emission of CO<sub>2</sub> in grams per kilometre

M<sub>1</sub> = mass emission of CO<sub>2</sub> in grams per kilometre with a fully charged electrical energy/power storage device

$M_2$  = mass emission of CO<sub>2</sub> in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

$D_e$  = vehicle's electric range, according to the procedure described in Annex 9, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

$D_{av}$  = 25 km (assumed average distance between two battery recharges)

### 3.4.2.2. In the case of testing according to paragraph 3.2.3.2.2.:

$$M = (D_{ovc} \cdot M_1 + D_{av} \cdot M_2) / (D_{ovc} + D_{av})$$

Where:

$M$  = mass emission of CO<sub>2</sub> in grams per kilometre

$M_1$  = mass emission of CO<sub>2</sub> in grams per kilometre with a fully charged electrical energy/power storage device

$M_2$  = mass emission of CO<sub>2</sub> in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

$D_{ovc}$  = OVC range according to the procedure described in Annex 9

$D_{av}$  = 25 km (assumed average distance between two battery recharges)

3.4.3. The values of fuel consumption shall be

$$C_1 = 100 \cdot c_1 / D_{test1} \text{ and } C_2 = 100 \cdot c_2 / D_{test2} \text{ [l/100 km]}$$

with  $D_{test1}$  and  $D_{test2}$  the **total** actual driven distances in the tests performed under conditions A (paragraph 3.2. of this annex) and B (paragraph 3.3. of this annex) respectively, and  $c_1$  and  $c_2$  determined in paragraphs 3.2.3.5. and 3.3.2.5. of this annex respectively.

3.4.4. The weighted values of fuel consumption shall be calculated as below:

### 3.4.4.1. In the case of test procedure according to par. 3.2.3.2.1.:

$$C = (D_e \cdot C_1 + D_{av} \cdot C_2) / (D_e + D_{av})$$

Where:

$C$  = fuel consumption in l/100 km.

$C_1$  = fuel consumption in l/100 km with a fully charged electrical energy/power storage device

$C_2$  = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

$D_e$  = vehicle's electric range, according to the procedure described in Annex 9, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

$D_{av}$  = 25 km (assumed average distance between two battery recharges)

#### 3.4.4.2. In the case of testing according to paragraph 3.2.3.2.2.:

$$C = (D_{ovc} \cdot C_1 + D_{av} \cdot C_2) / (D_{ovc} + D_{av})$$

Where:

$C$  = fuel consumption in l/100 km.

$C_1$  = fuel consumption in l/100 km with a fully charged electrical energy/power storage device

$C_2$  = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

$D_{ovc}$  = OVC range according to the procedure described in Annex 9

$D_{av}$  = 25 km (assumed average distance between two battery recharges)

3.4.5. The values of electric energy consumption shall be:

$$E_1 = e_1 / D_{test1} \text{ and } E_4 = e_4 / D_{test2} \text{ [Wh/km]}$$

with  $D_{test1}$  and  $D_{test2}$  the **total** actual driven distances in the tests performed under conditions A (paragraph 3.2. of this annex) and B (paragraph 3.3. of this annex) respectively, and  $e_1$  and  $e_4$  determined in paragraphs 3.2.5. and 3.3.7. of this annex respectively.

3.4.6. The weighted values of electric energy consumption shall be calculated as below:

#### 3.4.6.1. In the case of testing according to paragraph 3.2.3.2.1.:

$$E = (D_e \cdot E_1 + D_{av} \cdot E_4) / (D_e + D_{av})$$

Where:

$E$  = electric consumption Wh/km

$E_1$  = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated

$E_4$  = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

$D_e$  = vehicle's electric range, according to the procedure described in Annex 9, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state



$D_{av} = 25$  km (assumed average distance between two battery recharges)

**3.4.6.2. In the case of testing according to paragraph 3.2.3.2.2.:**

$$E = (D_{ovc} \cdot E_1 + D_{av} \cdot E_4) / (D_{ovc} + D_{av})$$

**Where:**

- E** = electric consumption Wh/km
- E<sub>1</sub>** = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated
- E<sub>4</sub>** = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)
- D<sub>ovc</sub>** = OVC range according to the procedure described in Annex 9
- D<sub>av</sub>** = 25 km (assumed average distance between two battery recharges)

**4. EXTERNALLY CHARGEABLE (OVC HEV) WITH AN OPERATING MODE SWITCH**

4.1. Two tests shall be performed under the following conditions:

4.1.1. Condition A: test shall be carried out with a fully charged electrical energy/power storage device.

4.1.2. Condition B: test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

4.1.3. The operating mode switch shall be positioned according to the table below:

Hybrid-modes	↵ Pure electric ↵ Hybrid	↵ Pure fuel consuming ↵ Hybrid	↵ Pure electric ↵ Pure fuel consuming ↵ Hybrid	↵ Hybrid mode n*/ ↵ ... ↵ Hybrid mode m*
Battery state of charge	Switch in position	Switch in position	Switch in position	Switch in position
Condition A Fully charged	Hybrid	Hybrid	Hybrid	Most electric hybrid mode**/
Condition B Min. state of charge	Hybrid	Fuel consuming	Fuel consuming	Most fuel consuming mode***/

\*/ for instance: sport, economic, urban, extra-urban position ...

\*\*/ Most electric hybrid mode:

The hybrid mode which can be proven to have the highest electricity consumption of all selectable hybrid modes when tested in accordance with condition A, to be

established based on information provided by the manufacturer and in agreement with the technical service.

\*\*\*/

Most fuel consuming mode:

The hybrid mode which can be proven to have the highest fuel consumption of all selectable hybrid modes when tested in accordance with condition B, to be established based on information provided by the manufacturer and in agreement with the technical service.

#### 4.2. Condition A

4.2.1. If the electric range of the vehicle, as measured in accordance with Annex 9 to this Regulation, is higher than 1 complete cycle, on the request of the manufacturer, the type I test for electric energy measurement may be carried out in pure electric mode, after agreement of the technical service. In this case, the values of  $M_1$  and  $C_1$  in paragraph 4.4. are equal to 0.

4.2.2. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle as described in paragraph 4.2.2.1. below.

4.2.2.1. The electrical energy/power storage device of the vehicle is discharged while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per cent  $\pm$  5 per cent of the maximum speed of the vehicle in pure electric mode, which is to be determined according to the test procedure for electric vehicles defined in Regulation No. 68.

Stopping the discharge occurs:

- (a) when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed; or
- (b) when an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or
- (c) after covering a distance of 100 km.

If the vehicle is not equipped with a pure electric mode, the electrical energy/power storage device discharge shall be achieved by driving the vehicle (on the test track, on a chassis dynamometer, etc.):

- (a) at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up,
- (b) or if a vehicle can not reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer),
- (c) or with manufacturer's recommendation.

The fuel-consuming engine shall be stopped within 10 seconds of it being automatically started.

- 4.2.3. Conditioning of the vehicle:
- 4.2.3.1. For conditioning compression-ignition engines the Part Two cycle of the applicable driving cycle shall be used in combination with the applicable gear shifting prescriptions as defined in paragraph 1.4. of this annex. Three consecutive cycles shall be driven.
- 4.2.3.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two cycles of the applicable driving cycle in combination with the applicable gear shifting prescriptions as defined in paragraph 1.4. of this annex.
- 4.2.3.3. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within  $\pm 2$  K of the temperature of the room, and the electrical energy/power storage device is fully charged as a result of the charging prescribed in paragraph 4.2.3.4. below.
- 4.2.3.4. During soak, the electrical energy/power storage device shall be charged, using the normal overnight charging procedure as defined in paragraph 3.2.2.5. of this annex.
- 4.2.4. Test procedure
- 4.2.4.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.
- 4.2.4.2. **The test procedures defined in either paragraph 4.2.4.2.1. or 4.2.4.2.2. may be used.**
- 4.2.4.2.1. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).
- 4.2.4.2.2. **Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and continue over a number of repeat test cycles. It shall end on conclusion of the final idling period in the first extra-urban (Part Two) cycle during which the battery reached the minimum state of charge according to the criterion defined below (end of sampling (ES)).**

**The electricity balance Q [Ah] is measured over each combined cycle, using the procedure specified in Appendix 2 to this annex, and used to determine when the battery minimum state of charge has been reached.**

**The battery minimum state of charge is considered to have been reached in combined cycle N if the electricity balance measured during combined cycle**

**N+1 is not more than a 3 per cent discharge, expressed as a percentage of the nominal capacity of the battery (in Ah) in its minimum state of charge, as declared by the manufacturer. At the manufacturer's request additional test cycles may be run and their results included in the calculations in paragraphs 4.2.4.5. and 4.4.1. provided that the electricity balance for each additional test cycle shows less discharge of the battery than over the previous cycle.**

**In between each of the cycles a hot soak period of up to 10 minutes is allowed. The powertrain shall be switched off during this period.**

- 4.2.4.3. The vehicle shall be driven using the applicable driving cycle and gear shifting prescriptions as defined in paragraph 1.4. to this annex.
- 4.2.4.4. The exhaust gases shall be analysed according to Annex 4 of Regulation No. 83 in force at the time of approval of the vehicle.
- 4.2.4.5. The test results on the combined cycle (CO<sub>2</sub> and fuel consumption) for Condition A shall be recorded (respectively  $m_1$  [g] and  $c_1$  [l]). **In the case of testing according to paragraph 4.2.4.2.1.,  $m_1$  and  $c_1$  are simply the results of the single combined cycle run. In the case of testing according to paragraph 4.2.4.2.2.,  $m_1$  and  $c_1$  are the sums of the results of the N combined cycles run.**

$$m_1 = \sum_1^N m_i \quad c_1 = \sum_1^N c_i$$

- 4.2.5. Within the 30 minutes after the conclusion of the **last** cycle, the electrical energy/power storage device shall be charged according to paragraph 3.2.2.5. of this annex).

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy  $e_1$  [Wh] delivered from the mains.

- 4.2.6. The electric energy consumption for condition A is  $e_1$  [Wh].

#### 4.3. Condition B

##### 4.3.1. Conditioning of the vehicle

- 4.3.1.1. The electrical energy/power storage device of the vehicle shall be discharged according to paragraph 4.2.2.1. of this annex.

At the manufacturer's request, a conditioning according to paragraph 4.2.3.1. or 4.2.3.2. of this annex may be carried out before electrical energy / power storage discharge.

- 4.3.1.2. Before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within  $\pm 2$  K of the temperature of the room.
- 4.3.2. Test procedure
- 4.3.2.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.
- 4.3.2.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).
- 4.3.2.3. The vehicle shall be driven using the applicable driving cycle and gear shifting prescriptions as defined in paragraph 1.4. to this annex
- 4.3.2.4. The exhaust gases shall be analysed according Annex 4 of Regulation No. 83 in force at the time of approval of the vehicle.
- 4.3.2.5. The test results on the combined cycle (CO<sub>2</sub> and fuel consumption) for Condition B shall be recorded (respectively  $m_2$  [g] and  $c_2$  [l]).
- 4.3.3. Within the 30 minutes after the conclusion of the cycle, the electrical energy/power storage device shall be charged according to paragraph 3.2.2.5. of this annex.
- The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy  $e_2$  [Wh] delivered from the mains.
- 4.3.4. The electrical energy/power storage device of the vehicle shall be discharged in accordance with paragraph 4.2.2.1. of this annex.
- 4.3.5. Within 30 minutes after the discharge, the electrical energy/power storage device shall be charged according to paragraph 3.2.2.5. of this annex.
- The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy  $e_3$  [Wh] delivered from the mains.
- 4.3.6. The electric energy consumption  $e_4$  [Wh] for condition B is:  $e_4 = e_2 - e_3$
- 4.4. Test results
- 4.4.1. The values of CO<sub>2</sub> shall be  $M_1 = m_1/D_{test1}$  and  $M_2 = m_2/D_{test2}$  [g/km] with  $D_{test1}$  and  $D_{test2}$  the **total** actual driven distances in the tests performed under conditions A (paragraph 4.2. of this annex) and B (paragraph 4.3. of this annex) respectively,

and  $m_1$  and  $m_2$  determined in paragraphs 4.2.3.5. and 4.3.2.5. of this annex respectively.

4.4.2. The weighted values of CO<sub>2</sub> shall be calculated as below:

**4.4.2.1. In the case of testing according to paragraph 4.2.4.2.1.:**

$$M = (D_e \cdot M_1 + D_{av} \cdot M_2) / (D_e + D_{av})$$

Where:

- $M$  = mass emission of CO<sub>2</sub> in grams per kilometre
- $M_1$  = mass emission of CO<sub>2</sub> in grams per kilometre with a fully charged electrical energy/power storage device
- $M_2$  = mass emission of CO<sub>2</sub> in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)
- $D_e$  = vehicle's electric range, according to the procedure described in Annex 9, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.
- $D_{av}$  = 25 km (assumed average distance between two battery recharges)

**4.4.2.2. In the case of testing according to paragraph 4.2.4.2.2.:**

$$M = (D_{ovc} \cdot M_1 + D_{av} \cdot M_2) / (D_{ovc} + D_{av})$$

Where

- $M$  = mass emission of CO<sub>2</sub> in grams per kilometre
- $M_1$  = mass emission of CO<sub>2</sub> in grams per kilometre with a fully charged electrical energy/power storage device
- $M_2$  = mass emission of CO<sub>2</sub> in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)
- $D_{ovc}$  = OVC range according to the procedure described in Annex 9
- $D_{av}$  = 25 km (assumed average distance between two battery recharges)

4.4.3. The values of fuel consumption shall be:

$$C_1 = 100 \cdot c_1 / D_{test1} \text{ and } C_2 = 100 \cdot c_2 / D_{test2} \text{ [l/100 km]}$$

with  $D_{test1}$  and  $D_{test2}$  the **total** actual driven distances in the tests performed under conditions A (paragraph 4.2. of this annex) and B (paragraph 4.3. of this annex) respectively, and  $c_1$  and  $c_2$  determined in paragraphs 4.2.4.5. and 4.3.2.5. of this annex respectively.

4.4.4. The weighted values of fuel consumption shall be calculated as below:

**4.4.4.1 In the case of testing according to paragraph 4.2.4.2.1.:**

$$C = (D_e \cdot C_1 + D_{av} \cdot C_2) / (D_e + D_{av})$$

Where:

**C** = fuel consumption in l/100 km.

**C<sub>1</sub>** = fuel consumption in l/100 km with a fully charged electrical energy/power storage device

**C<sub>2</sub>** = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

**D<sub>e</sub>** = vehicle's electric range, according to the procedure described in Annex 9, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state.

**D<sub>av</sub>** = 25 km (assumed average distance between two battery recharges)

**4.4.4.2 In the case of testing according to paragraph 4.2.4.2.2.:**

$$C = (D_{ovc} \cdot C_1 + D_{av} \cdot C_2) / (D_{ovc} + D_{av})$$

Where:

**C** = fuel consumption in l/100 km.

**C<sub>1</sub>** = fuel consumption in l/100 km with a fully charged electrical energy/power storage device

**C<sub>2</sub>** = fuel consumption in l/100 km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

**D<sub>ovc</sub>** = OVC range according to the procedure described in Annex 9

**D<sub>av</sub>** = 25 km (assumed average distance between two battery recharges)

4.4.5. The values of electric energy consumption shall be:

$$E_1 = e_1 / D_{test1} \text{ and } E_4 = e_4 / D_{test2} \text{ [Wh/km]}$$

with **D<sub>test1</sub>** and **D<sub>test2</sub>** the **total** actual driven distances in the tests performed under conditions A (paragraph 4.2. of this annex) and B (paragraph 3.3. of this annex) respectively, and **e<sub>1</sub>** and **e<sub>4</sub>** determined in paragraphs 4.2.6. and 4.3.6. of this annex respectively.

4.4.6. The weighted values of electric energy consumption shall be calculated as below:

**4.4.6.1 In the case of testing according to paragraph 4.2.4.2.1.:**

$$E = (D_e \cdot E_1 + D_{av} \cdot E_4) / (D_e + D_{av})$$

Where:

- E = electric consumption Wh/km
- E<sub>1</sub> = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated
- E<sub>4</sub> = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)
- D<sub>e</sub> = vehicle's electric range, according to the procedure described in Annex 9, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric operating state
- D<sub>av</sub> = 25 km (assumed average distance between two battery recharges)

#### 4.4.6.2 In the case of testing according to paragraph 4.2.4.2.2.:

$$E = (D_{ovc} \cdot E_1 + D_{av} \cdot E_4) / (D_{ovc} + D_{av})$$

Where:

- E = electric consumption Wh/km,**
- E<sub>1</sub> = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated,**
- E<sub>4</sub> = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity),**
- D<sub>ovc</sub> = OVC range according to the procedure described in Annex 9,**
- D<sub>av</sub> = 25 km (assumed average distance between two battery recharges). "**



Annex 8, Appendix 2, amend to read:

"Annex 8 - Appendix 2

METHOD FOR MEASURING THE ELECTRICITY BALANCE OF  
THE BATTERY OF **OVC AND NOVC HEVS**

1. Introduction

- 1.1. The purpose of this appendix is to define the method and required instrumentation for measuring the electricity balance of **Off Vehicle Charging Hybrid Electric Vehicles (OVC HEV and Not Off Vehicle Charging Hybrid Electric Vehicles (NOVC HEVs)**. Measurement of the electricity balance is necessary
- (a) **to determine when the minimum state of charge of the battery has been reached during the test procedure defined in paragraphs 3. and 4. of this annex; and**
- (b) to correct the measured fuel consumption and CO<sub>2</sub>-emissions for the change in battery energy content occurring during the test, using the method defined in paragraphs 5. and 6. of this annex.
- 1.2. The method described in this annex shall be used by the manufacturer for the measurements that are performed to determine the correction factors  $K_{\text{fuel}}$  and  $K_{\text{CO}_2}$ , as defined in paragraphs 5.3.3.2., 5.3.5.2., 6.3.3.2., and 6.3.5.2. of this annex.

The Technical Service shall check whether these measurements have been performed in accordance with the procedure described in this annex.

- 1.3. The method described in this annex shall be used by the Technical Service for the measurement of the electricity balance  $Q$ , as defined in paragraphs **3.2.3.2.2., 4.2.4.2.2., 5.3.4.1., 5.3.6.1., 6.3.4.1., and 6.3.6.1.** of this annex.

2. Measurement equipment and instrumentation

- 2.1. During the tests as described in paragraphs **3., 4., 5. and 6.** of this annex, the battery current shall be measured using a current transducer of the clamp-on type or the closed type. The current transducer (i.e. the current sensor without data acquisition equipment) shall have a minimum accuracy of 0.5 per cent of the measured value (**in A**) or 0.1 per cent of the maximum value of the scale.

OEM diagnostic testers are not to be used for the purpose of this test.

- 2.1.1. The current transducer shall be fitted on one of the wires directly connected to the battery. In order to easily measure battery current using external measuring equipment, manufacturers should preferably integrate appropriate, safe and accessible connection points in the vehicle. If that is not feasible, the manufacturer is obliged to support the Technical Service by providing the means to connect a current transducer to the wires connected to the battery in the above described manner.

- 2.1.2. The output of the current transducer shall be sampled with a minimum sample frequency of 5 Hz. The measured current shall be integrated over time, yielding the measured value of Q, expressed in Ampere hours (Ah).
- 2.1.3. The temperature at the location of the sensor shall be measured and sampled with the same sample frequency as the current, so that this value can be used for possible compensation of the drift of current transducers and, if applicable, the voltage transducer used to convert the output of the current transducer.
- 2.2. A list of the instrumentation (manufacturer, model no., serial no.) used by the manufacturer for determining:
  - (a) **when the minimum state of charge of the battery has been reached during the test procedure defined in paragraphs 3. and 4. of this annex; and**
  - (b) the correction factors  $K_{\text{fuel}}$  and  $K_{\text{CO}_2}$  (as defined in paragraphs 5.3.3.2., 5.3.5.2., 6.3.3.2., and 6.3.5.2. of this annex)and the last calibration dates of the instruments (where applicable) should be provided to the Technical Service.
3. Measurement procedure
  - 3.1. Measurement of the battery current shall start at the same time as the test starts and shall end immediately after the vehicle has driven the complete driving cycle.
  - 3.2. Separate values of Q shall be logged over the Part One and Part Two of the cycle."

Annex 9, amend to read:

"Annex 9

**METHOD OF MEASURING THE ELECTRIC RANGE OF VEHICLES POWERED BY AN ELECTRIC POWER TRAIN ONLY OR BY A HYBRID ELECTRIC POWER TRAIN AND THE OVC RANGE OF VEHICLES POWERED BY A HYBRID ELECTRIC POWERTRAIN**

1. MEASUREMENT OF THE ELECTRIC RANGE

The test method described hereafter permits to measure the electric range, expressed in km, of vehicles powered by an electric power train only or **the electric range and OVC range** of vehicles powered by a hybrid electric power train with off-vehicle charging (OVC-HEV as defined in paragraph 2. of Annex 8).

2. PARAMETERS, UNITS AND ACCURACY OF MEASUREMENTS

Parameters, units and accuracy of measurements shall be as follows:

Parameter	Unit	Accuracy	Resolution
Time	s	+/- 0.1 s	0.1 s
Distance	m	+/- 0.1 per cent	1 m
Temperature degrees	C	+/- 1 degree C	1 degree C
Speed	km/h	+/- 1 per cent	0.2 km/h
Mass	kg	+/- 0.5 per cent	1 kg
<b>Electricity balance</b>	<b>Ah</b>	<b>+/- 0.5 per cent</b>	<b>0.3 per cent</b>

3. TEST CONDITIONS

3.1. Condition of the vehicle

3.1.1. The vehicle tyres shall be inflated to the pressure specified by the vehicle manufacturer when the tyres are at the ambient temperature.

3.1.2. The viscosity of the oils for the mechanical moving parts shall conform to the specifications of the vehicle manufacturer.

3.1.3. The lighting and light-signalling and auxiliary devices shall be off, except those required for testing and usual daytime operation of the vehicle.

3.1.4. All energy storage systems available for other than traction purposes (electric, hydraulic, pneumatic, etc.) shall be charged up to their maximum level specified by the manufacturer.

3.1.5. If the batteries are operated above the ambient temperature, the operator shall follow the procedure recommended by the vehicle manufacturer in order to keep

the temperature of the battery in the normal operating range.

The manufacturer's agent shall be in a position to attest that the thermal management system of the battery is neither disabled nor reduced.

3.1.6. The vehicle must have undergone at least 300 km during the seven days before the test with those batteries that are installed in the test vehicle.

3.2. Climatic conditions

For testing performed outdoors, the ambient temperature shall be between 5 °C and 32 °C.

The indoors testing shall be performed at a temperature between 20 °C and 30 °C.

4. OPERATION MODES

The test method includes the following steps:

- (a) Initial charge of the battery.
- (b) Application of the cycle and measurement of the electric range.

Between the steps, if the vehicle shall move, it is pushed to the following test area (without regenerative recharging).

4.1. Initial charge of the battery

Charging the battery consists of the following procedures:

Note: "Initial charge of the battery" applies to the first charge of the battery, at the reception of the vehicle. In case of several combined tests or measurements, carried out consecutively, the first charge carried out shall be an "initial charge of the battery" and the following may be done in accordance with the "normal overnight charge" procedure.

4.1.1. Discharge of the battery

4.1.1.1. For pure electric vehicles:

4.1.1.1.1. The procedure starts with the discharge of the battery of the vehicle while driving (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per cent +/- 5 percent from the maximum thirty minutes speed of the vehicle.

4.1.1.1.2. Stopping the discharge occurs:

- (a) when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed;
- (b) or when an indication to stop the vehicle is given to the driver by the standard onboard instrumentation, or
- (c) after covering the distance of 100 km.

- 4.1.1.2. For externally chargeable hybrid electric vehicle (OVC HEV) without an operating mode switch as defined in Annex 8:
- 4.1.1.2.1. The manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state.
- 4.1.1.2.2. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.):
- (a) at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up,
  - (b) or, if a vehicle can not reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run at a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer),
  - (c) or with manufacturer's recommendation.
- The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.
- 4.1.1.3. For externally chargeable hybrid electric vehicle (OVC HEV) with an operating mode switch as defined in Annex 8:
- 4.1.1.3.1. If there is not a pure electric position, the manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state.
- 4.1.1.3.2. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per cent +/- 5 per cent of the maximum thirty minutes speed of the vehicle.
- 4.1.1.3.3. Stopping the discharge occurs:
- (a) when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed; or
  - (b) when an indication to stop the vehicle is given to the driver by the standard onboard instrumentation, or
  - (c) after covering the distance of 100 km.
- 4.1.1.3.4. If the vehicle is not equipped with a pure electric operating state, the electrical energy/ power storage device discharge shall be achieved by driving the vehicle (on the test track, on a chassis dynamometer, etc.):
- (a) at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up, or
  - (b) if a vehicle can not reach a steady speed of 50 km/h without starting up the

fuel consuming engine , the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer), or

- (c) with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

#### 4.1.2. Application of a normal overnight charge

For a pure electric vehicle, the battery shall be charged according to the normal overnight charge procedure, as defined in paragraph 2.4.1.2. of Annex 7, for a period not exceeding 12 hours.

For an OVC HEV, the battery shall be charged according to the normal overnight charge procedure as described in paragraph 3.2.2.5. of Annex 8.

#### 4.2. Application of the cycle and measurement of the range

##### 4.2.1. For pure electric vehicle:

4.2.1.1. The test sequence as defined in paragraph 1.1. of Annex 7 is applied on a chassis dynamometer adjusted as described in appendix 1 of Annex 7, until the end of the test criteria is reached.

4.2.1.2. The end of the test criteria is reached when the vehicle is not able to meet the target curve up to 50 km/h, or when an indication from the standard on-board instrumentation is given to the driver to stop the vehicle.

Then the vehicle shall be slowed down to 5 km/h by releasing the accelerator pedal, without touching the brake pedal and then stopped by braking.

4.2.1.3. At a speed over 50 km/h, when the vehicle does not reach the required acceleration or speed of the test cycle, the accelerator pedal shall remain fully depressed until the reference curve has been reached again.

4.2.1.4. To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total.

4.2.1.5. At the end, the measure  $D_e$  of the covered distance in km is the electric range of the electric vehicle. It shall be rounded to the nearest whole number

##### 4.2.2. For hybrid electric vehicles

##### 4.2.2.1. **To determine the electric range of a hybrid electric vehicle**

- 4.2.2.1.1.** The applicable test sequence and accompanying gear shift prescription, as defined in paragraph 1.4. of Annex 8, is applied on a chassis dynamometer adjusted as described in Appendices 2, 3, and 4 of Annex 4 of Regulation No. 83, until the end of the test criteria is reached.
- 4.2.2.1.2.** To measure the **electric range** the end of the test criteria is reached when the vehicle is not able to meet the target curve up to 50 km/h, or when an indication from the standard on-board instrumentation is given to the driver to stop the vehicle or **when the battery has reached its minimum state of charge**. Then the vehicle shall be slowed down to 5 km/h by releasing the accelerator pedal, without touching the brake pedal and then stopped by braking.
- 4.2.2.1.3.** At a speed over 50 km/h, when the vehicle does not reach the required acceleration or speed of the test cycle, the accelerator pedal shall remain fully depressed until the reference curve has been reached again.
- 4.2.2.1.4.** To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total.
- 4.2.2.1.5.** At the end, the measure  $D_e$  of the distance covered **using the electrical motor only** in km is the electric range of the hybrid electric vehicle. It shall be rounded to the nearest whole number. **Where the vehicle operates both in electric and hybrid modes during the test, the periods of electric only operation will be determined by measuring current to the injectors or ignition.**
- 4.2.2.2.** **To determine the OVC range of a hybrid electric vehicle**
- 4.2.2.2.1.** **The applicable test sequence and accompanying gear shift prescription, as defined in paragraph 1.4. of Annex 8, is applied on a chassis dynamometer adjusted as described in Appendices 2, 3, and 4 of Annex 4 of Regulation No. 83, until the end of the test criteria is reached.**
- 4.2.2.2.2.** **To measure the OVC range the end of the test criteria is reached when the battery has reached its minimum state of charge according to the criteria defined in Annex 8, paragraph 3.2.3.2.2. or 4.2.4.2.2. Driving is continued until the final idling period in the extra-urban cycle.**
- 4.2.2.2.3.** **To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total.**
- 4.2.2.2.4.** **At the end, the total distance driven in km, rounded to the nearest whole number, is the OVC range of the hybrid electric vehicle."**

## B. JUSTIFICATION

Regulation No. 101 requires testing of externally chargeable, or 'Off Vehicle Charging' (OVC), hybrid vehicles in two states of battery charge, full charge and a low charge level. At the present time, a weighted average of the results of these two tests is calculated using the pure electric range of the vehicle and a nominal value for the typical distance between recharges. This procedure works well for vehicles designed to run in pure electric mode until the battery reaches a minimum charge level and then start the internal combustion engine. However, the procedure penalises vehicles which preserve the charge imparted to the battery, by starting the internal combustion engine earlier, whenever energy demands are high e.g. at higher vehicle speeds or higher rates of acceleration. In this case, the weighting attached to the high charge test result is artificially low as the electric range of the vehicle is defined by the point at which the control strategy starts the internal combustion engine, rather than the point at which the energy imparted from the off-vehicle charging has been exhausted.

The above proposal introduces the concept of an OVC range, defined as the distance travelled in the number of complete NEDC cycles that can be driven before the battery reaches a stable minimum state of charge. Manufacturers are given the option of using this range, instead of the electric range, in calculating the weighted average CO<sub>2</sub> and fuel consumption. The point, at which the minimum state of battery charge is reached, is determined by integrating charge into and out of the battery over each successive test cycle. Minimum state of charge is assumed to be reached when the net discharge of the battery over a cycle is < 3 per cent of the nominal capacity of the battery in its minimum state of charge. This 3 per cent tolerance is based on the repeatability of current OVC vehicles. Where manufacturers believe a tighter tolerance is applicable, they may continue testing provided each successive test cycle continues to show a net discharge of the battery.

Under this option the results for condition A (maximum state of battery charge) are determined by conducting repeat test cycles until the battery stable minimum state of charge is reached. The condition A results, used in calculating weighted average CO<sub>2</sub>, fuel and electrical energy consumption, are the average results calculated across the total distance travelled in the repeat cycles.

For determining electric range, the point at which the battery reaches its minimum state of charge has been added as an option for determining the end of test. However, only distance travelled solely under electric power is counted towards the electric range, any distance travelled with the internal combustion engine operating, before minimum state of battery charge is reached, is excluded. Where the proposed new test procedure is followed, measurement of range under pure electric propulsion is required for reference purposes only.

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