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7 May 2002

AGREEMENT

**CONCERNING THE ADOPTION OF UNIFORM TECHNICAL PRESCRIPTIONS
FOR WHEELED VEHICLES, EQUIPMENT AND PARTS WHICH CAN BE FITTED AND/OR
BE USED ON WHEELED VEHICLES AND THE CONDITIONS FOR RECIPROCAL RECOGNITION OF
APPROVALS GRANTED ON THE BASIS OF THESE PRESCRIPTIONS */**

(Revision 2, including the amendments which entered into force on 16 October 1995)

Addendum 99: Regulation No. 100

Amendment 1

Supplement 1 to the original version of the Regulation - Date of entry into force: 21 February 2002

**UNIFORM PROVISIONS CONCERNING THE APPROVAL OF BATTERY ELECTRIC VEHICLES WITH
REGARD TO SPECIFIC REQUIREMENTS FOR THE CONSTRUCTION AND FUNCTIONAL SAFETY**



UNITED NATIONS

*/ Former title of the Agreement:

Agreement Concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts, done at Geneva on 20 March 1958.

GE.02-21899

The title of the Regulation, amend to read:

"UNIFORM PROVISIONS CONCERNING THE APPROVAL OF BATTERY ELECTRIC VEHICLES
WITH REGARD TO SPECIFIC REQUIREMENTS FOR THE CONSTRUCTION,
FUNCTIONAL SAFETY AND HYDROGEN EMISSION"

Paragraph 4.1., amend to read:

"4.1. If the vehicle submitted for approval pursuant to this Regulation meets the requirements of paragraph 5 below and annexes 3, 4, 5 and 7 to this Regulation, approval of this vehicle type shall be granted."

Paragraph 4.4.1., footnote 1/, amend to read:

"1/ 1 for Germany, 2 for France, 3 for Italy, 4 for the Netherlands, 5 for Sweden, 6 for Belgium, 7 for Hungary, 8 for the Czech Republic, 9 for Spain, 10 for Yugoslavia, 11 for the United Kingdom, 12 for Austria, 13 for Luxembourg, 14 for Switzerland, 15 (vacant), 16 for Norway, 17 for Finland, 18 for Denmark, 19 for Romania, 20 for Poland, 21 for Portugal, 22 for the Russian Federation, 23 for Greece, 24 for Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32 for Latvia, 33 (vacant), 34 for Bulgaria, 35 (vacant), 36 for Lithuania, 37 for Turkey, 38 (vacant), 39 for Azerbaijan, 40 for The former Yugoslav Republic of Macedonia, 41 (vacant), 42 for the European Community (Approvals are granted by its Member States using their respective ECE symbol), 43 for Japan, 44 (vacant), 45 for Australia, 46 for Ukraine, 47 for South Africa and 48 for New Zealand. Subsequent numbers shall be assigned to other countries in the chronological order in which they ratify or accede to the Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement."

Insert a new paragraph 5.3., to read:

"5.3. Determination of hydrogen emissions

5.3.1. This test must be carried out on all battery electric road vehicles referred to in paragraph 1 of this Regulation.

Road vehicles equipped with non-aqueous electrolyte batteries or sealed "gas recombinant "batteries are excluded.

5.3.2. The test must be conducted following the method described in annex 7 to the present Regulation. The hydrogen sampling and analysis must be the ones prescribed. Other analysis methods can be approved if it is proven that they give equivalent results.

- 5.3.3. During a normal charge procedure in the conditions given in annex 7, hydrogen emissions must be below 125 g during 5 h, or below $25 \times t_2$ g during t_2 (in h).
- 5.3.4. During a charge carried out by an on-board charger presenting a failure (conditions given in annex 7), hydrogen emissions must be below 42 g. Furthermore the on-board charger must limit this possible failure to 30 minutes.
- 5.3.5. All the operations linked to the battery charging are controlled automatically, included the stop for charging.
- 5.3.6. It shall not be possible to take a manual control of the charging phases.
- 5.3.7. Normal operations of connection and disconnection to the mains or power cuts must not affect the control system of the charging phases.
- 5.3.8. Important charging failures must be permanently signalled to the driver. An important failure is a failure that can lead to a disfunctioning of the on-board charger during charging later on.
- 5.3.9. The manufacturer has to indicate in the owner's manual, the conformity of the vehicle to these requirements.
- 5.3.10. The approval granted to a vehicle type relative to hydrogen emissions can be extended to different vehicle types belonging to the same family, in accordance with the definition of the family given in annex 7, appendix 2."

Annex 6, insert new paragraphs 4.2.2. to 4.2.4 and 5.6.1 to 5.6.8., and a footnote 2/ to read:

- "4.2.2. Number of battery cells
- 4.2.3. Number of battery modules
Gas combination rate (in per cent)
- 5.6.1. Make and type of different charger parts 2/
- 5.6.2. Drawing description of the charger 2/
Output nominal power (kW) 2/
Maximum voltage of charge (V) 2/
- 5.6.5. Maximum intensity of charge (A) 2/
Make and type of control unit (if any) 2/
- 5.6.7. Diagram of operating, controls and safety 2/

5.6.8. Description and characteristics of charge periods 2/

2/ For vehicles equipped with an on-board charger."

Insert a new Annex 7, with Appendices 1 and 2, to read:

"Annex 7

DETERMINATION OF HYDROGEN EMISSIONS
DURING THE CHARGE PROCEDURES OF THE TRACTION BATTERY

1. INTRODUCTION

This annex describes the procedure for the determination of hydrogen emissions during the charge procedures of the traction battery of all battery electric road vehicles, according to paragraph 5.3. of this Regulation.

2. DESCRIPTION OF TEST

The hydrogen emission test (Figure 7.1) is conducted in order to determine hydrogen emissions during the charge procedures of the traction battery with the on-board charger. The test consists in the following steps:

- (a) vehicle preparation,
- (b) discharge of the traction battery,
- (c) determination of hydrogen emissions during a normal charge,
- (d) determination of hydrogen emissions during a charge carried out with the on-board charger failure.

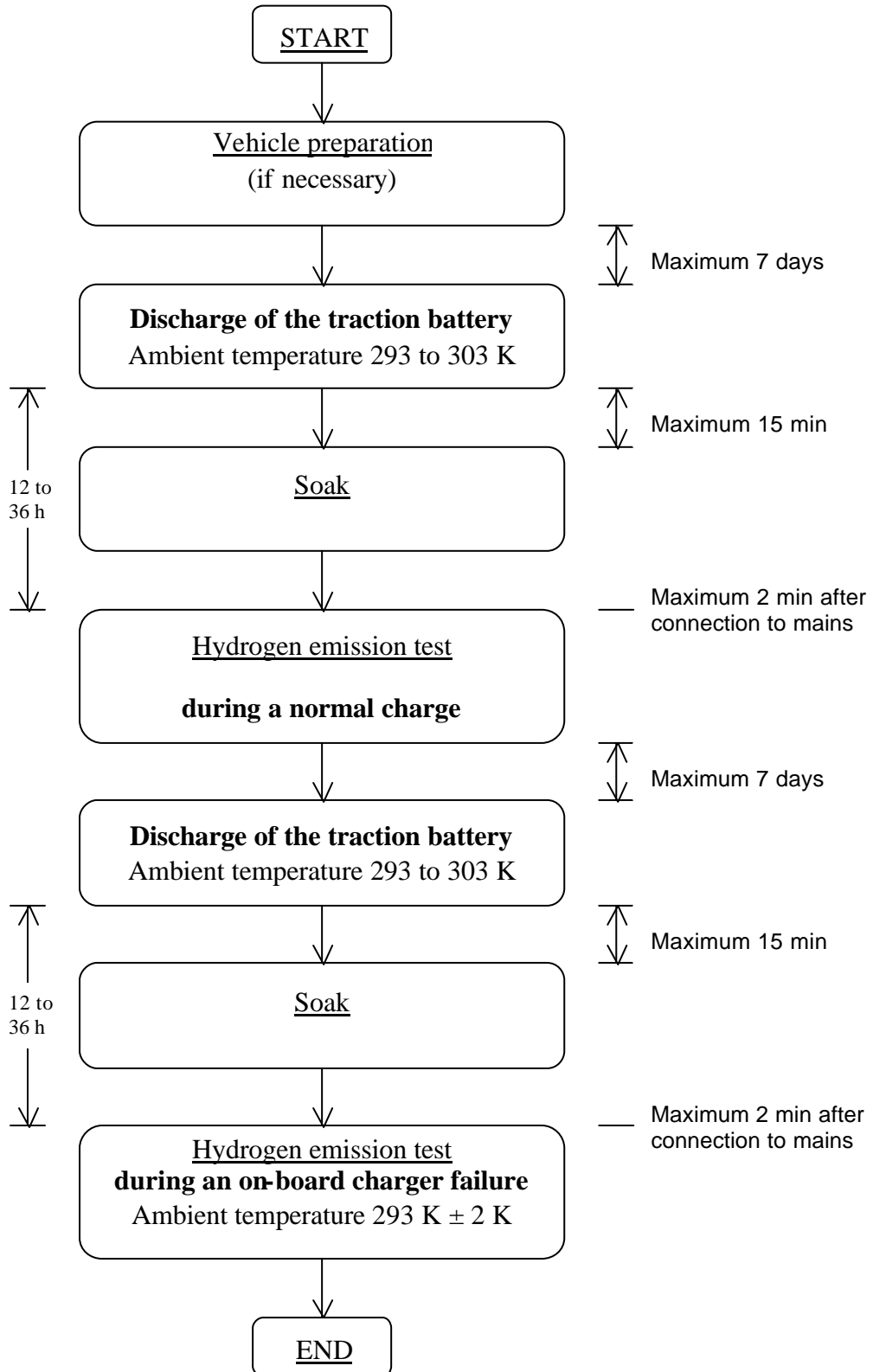
3. VEHICLE

3.1. The vehicle must be in good mechanical condition and have been driven at least 300 km during seven days before the test. The vehicle must be equipped with the traction battery subject to the test of hydrogen emissions, over this period.

3.2. If the battery is used at a temperature above the ambient temperature, the operator must follow the manufacturer's procedure in order to keep the traction battery temperature in normal functioning range.

The manufacturer's representative must be able to certify that the temperature conditioning system of the traction battery is neither damaged nor presenting a capacity defect.

Figure 7.1
**Determination of hydrogen emissions during
 the charge procedures of the traction battery**



4. TEST EQUIPMENT FOR HYDROGEN EMISSION TEST

4.1. Chassis dynamometer

The chassis dynamometer must meet the requirements of the 05 series of amendments to Regulation No. 83.

4.2. Hydrogen emission measurement enclosure

The hydrogen emission measurement enclosure must be a gas-tight measuring chamber able to contain the vehicle under test. The vehicle must be accessible from all sides and the enclosure when sealed must be gas-tight in accordance with appendix 1 to this annex. The inner surface of the enclosure must be impermeable and non-reactive to hydrogen. The temperature conditioning system must be capable of controlling the internal enclosure air temperature to follow the prescribed temperature throughout the test, with an average tolerance of ± 2 K over the duration of the test.

To accommodate the volume changes due to enclosure hydrogen emissions, either a variable-volume or another test equipment may be used. The variable-volume enclosure expands and contracts in response to the hydrogen emissions in the enclosure. Two potential means of accommodating the internal volume changes are movable panels, or a bellows design, in which impermeable bags inside the enclosure expand and contract in response to internal pressure changes by exchanging air from outside the enclosure. Any design for volume accommodation must maintain the integrity of the enclosure as specified in appendix 1 to this annex.

Any method of volume accommodation must limit the differential between the enclosure internal pressure and the barometric pressure to a maximum value of ± 5 hPa.

The enclosure must be capable of latching to a fixed volume. A variable volume enclosure must be capable of accommodating a change from its "nominal volume" (see annex 7, appendix 1, paragraph 2.1.1.), taking into account hydrogen emissions during testing.

4.3. Analytical systems

4.3.1. Hydrogen analyser

- 4.3.1.1. The atmosphere within the chamber is monitored using a hydrogen analyser (electrochemical detector type) or a chromatograph with thermal conductivity detection. Sample gas must be drawn from the mid-point of one side-wall or roof of the chamber and any bypass flow must be returned to the enclosure, preferably to a point immediately downstream of the mixing fan.

- 4.3.1.2 The hydrogen analyser must have a response time to 90 per cent of final reading of less than 10 seconds. Its stability must be better than 2 per cent of full scale at zero and at 80 per cent \pm 20 per cent of full scale, over a 15-minute period for all operational ranges.
- 4.3.1.3. The repeatability of the analyser expressed as one standard deviation must be better than 1 per cent of full scale, at zero and at 80 per cent \pm 20 per cent of full scale on all ranges used.
- 4.3.1.4. The operational ranges of the analyser must be chosen to give best resolution over the measurement, calibration and leak checking procedures.
- 4.3.2. Hydrogen analyser data recording system
- The hydrogen analyser must be fitted with a device to record electrical signal output, at a frequency of at least once per minute. The recording system must have operating characteristics at least equivalent to the signal being recorded and must provide a permanent record of results. The recording must show a clear indication of the beginning and end of the normal charge test and charging failure operation.
- 4.4. Temperature recording
- 4.4.1. The temperature in the chamber is recorded at two points by temperature sensors, which are connected so as to show a mean value. The measuring points are extended approximately 0.1 m into the enclosure from the vertical centre line of each side-wall at a height of 0.9 ± 0.2 m.
- 4.4.2. The temperatures of the battery modules are recorded by means of the sensors.
- 4.4.3. Temperatures must, throughout the hydrogen emission measurements, be recorded at a frequency of at least once per minute.
- 4.4.4. The accuracy of the temperature recording system must be within ± 1.0 K and the temperature must be capable of being resolved to ± 0.1 K.
- 4.4.5. The recording or data processing system must be capable of resolving time to ± 15 seconds.
- 4.5. Pressure recording
- 4.5.1. The difference Δp between barometric pressure within the test area and the enclosure internal pressure must, throughout the hydrogen emission measurements, be recorded at a frequency of at least once per minute.

4.5.2. The accuracy of the pressure recording system must be within ± 2 hPa and the pressure must be capable of being resolved to ± 0.2 hPa.

4.5.3. The recording or data processing system must be capable of resolving time to ± 15 seconds.

4.6. Voltage and current intensity recording

4.6.1. The on-board charger voltage and current intensity (battery) must, throughout the hydrogen emission measurements, be recorded at a frequency of at least once per minute.

4.6.2. The accuracy of the voltage recording system must be within ± 1 V and the voltage must be capable of being resolved to ± 0.1 V.

4.6.3. The accuracy of the current intensity recording system must be within ± 0.5 A and the current intensity must be capable of being resolved to ± 0.05 A.

4.6.4. The recording or data processing system must be capable of resolving time to ± 15 seconds.

4.7. Fans

The chamber must be equipped with one or more fans or blowers with a possible flow of 0.1 to 0.5 m³/second in order to thoroughly mix the atmosphere in the enclosure. It must be possible to reach a homogeneous temperature and hydrogen concentration in the chamber during measurements. The vehicle in the enclosure must not be subjected to a direct stream of air from the fans or blowers.

4.8. Gases

4.8.1. The following pure gases must be available for calibration and operation:

purified synthetic air (purity <1 ppm C₁ equivalent; <1 ppm CO; <400 ppm CO₂; <0.1 ppm NO); oxygen content between 18 and 21 per cent by volume,

hydrogen (H₂), 99.5 per cent minimum purity.

4.8.2. Calibration and span gases must contain mixtures of hydrogen (H₂) and purified synthetic air. The real concentrations of a calibration gas must be within ± 2 per cent of the nominal values. The accuracy of the diluted gases obtained when using a gas divider must be within ± 2 per cent of the nominal value. The concentrations specified in appendix 1 may also be obtained by a gas divider using synthetic air as the dilution gas.

5. TEST PROCEDURE

The test consists in the five following steps:

- (i) vehicle preparation,
- (ii) discharge of the traction battery,
- (iii) determination of hydrogen emissions during a normal charge,
- (iv) discharge of the traction battery,
- (v) determination of hydrogen emissions during a charge carried out with the on-board charger failure.

If the vehicle has to be moved between two steps, it shall be pushed to the following test area.

5.1. Vehicle preparation

The ageing of traction battery must be checked, proving that the vehicle has performed at least 300 km during seven days before the test. During this period, the vehicle must be equipped with the traction battery submitted to the hydrogen emission test. If this cannot be demonstrated then the following procedure will be applied.

5.1.1. Discharges and initial charges of the battery

The procedure starts with the discharge of the traction battery of the vehicle while driving on the test track or on a chassis dynamometer at a steady speed of 70 per cent \pm 5 per cent of the maximum speed of the vehicle during 30 minutes.

5.1.1.1. Discharging is stopped:

- (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 having covered the distance of 100 km.

5.1.1.2. Initial charge of the battery

The charge is carried out:

- (a) with the on-board charger,
- (b) in an ambient temperature between 293 K and 303 K.

The procedure excludes all types of external chargers.

The end of traction battery charge criteria corresponds to an automatic stop given by the on-board charger.

This procedure includes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges.

5.1.3. Procedure from paragraphs 5.1.1 to 5.1.2 must be repeated two times.

5.2. Discharge of the battery

The traction battery is discharged while driving on the test track or on a chassis dynamometer at a steady speed of 70 per cent \pm 5 per cent from the maximum thirty minutes speed of the vehicle.

Stopping the discharge occurs:

- (a) when an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or
- (b) when the maximum speed of the vehicle is lower than 20 km/h.

5.3. Soak

Within fifteen minutes of completing the battery discharge operation specified in 5.2, the vehicle is parked in the soak area. The vehicle is parked for a minimum of 12 hours and a maximum of 36 hours, between the end of the traction battery discharge and the start of the hydrogen emission test during a normal charge. For this period, the vehicle must be soaked at 293 K \pm 2 K.

5.4. Hydrogen emission test during a normal charge

5.4.1. Before the completion of the soak period, the measuring chamber must be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) must also be turned on at this time.

5.4.2. The hydrogen analyser must be zeroed and spanned immediately prior to the test.

5.4.3. At the end of the soak, the test vehicle, with the engine shut off and the test vehicle windows and luggage compartment opened must be moved into the measuring chamber.

The vehicle shall be connected to the mains. The battery is charged according to normal charge procedure as specified in paragraph 5.4.7. below.

5.4.5. The enclosure doors are closed and sealed gas-tight within two minutes from electrical interlock of the normal charge step.

- 5.4.6. The start of a normal charge for hydrogen emission test period begins when the chamber is sealed. The hydrogen concentration, temperature and barometric pressure are measured to give the initial readings C_{H2i} , T_i and P_i for the normal charge test.

These figures are used in the hydrogen emission calculation (paragraph 6.). The ambient enclosure temperature T must not be less than 291 K and no more than 295 K during the normal charge period.

- 5.4.7. Procedure of normal charge

The normal charge is carried out with the on-board charger and consists of the following steps:

- (a) Charging at constant power during t_1 .
- (b) Over-charging at constant current during t_2 . Over-charging intensity is specified by manufacturer and corresponds to the one used during equalisation charging.

The end of traction battery charge criteria corresponds to an automatic stop given by the on-board charger to a charging time of $t_1 + t_2$. This charging time will be limited to $t_1 + 5$ h, even if a clear indication is given to the driver by the standard instrumentation that the battery is not yet fully charged.

- 5.4.8. The hydrogen analyser must be zeroed and spanned immediately before the end of the test.
- 5.4.9. The end of the emission sampling period occurs $t_1 + t_2$ or $t_1 + 5$ h after the beginning of the initial sampling, as specified in paragraph 5.4.6. The different times elapsed are recorded. The hydrogen concentration, temperature and barometric pressure are measured to give the final readings C_{H2f} , T_f and P_f for the normal charge test, used for the calculation in paragraph 6.

5.5. Hydrogen emission test with the on-board charger failure

- 5.5.1 Within seven days maximum after having completed the prior test, the procedure starts with the discharge of the traction battery of the vehicle according to paragraph 5.2.
- 5.5.2. The steps of the procedure in paragraph 5.3 must be repeated.
- 5.5.3. Before the completion of the soak period, the measuring chamber must be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) must also be turned on at this time.

- 5.5.4. The hydrogen analyser must be zeroed and spanned immediately prior to the test.
- 5.5.5. At the end of the soak, the test vehicle, with the engine shut off and the test vehicle windows and luggage compartment opened must be moved into the measuring chamber.
- 5.5.6. The vehicle shall be connected to the mains. The battery is charged according to failure charge procedure as specified in paragraph 5.5.9. below.
- 5.5.7. The enclosure doors are closed and sealed gas-tight within two minutes from electrical interlock of the failure charge step.
- 5.5.8. The start of a failure charge for hydrogen emission test period begins when the chamber is sealed. The hydrogen concentration, temperature and barometric pressure are measured to give the initial readings C_{H_2i} , T_i and P_i for the failure charge test. These figures are used in the hydrogen emission calculation (paragraph 6). The ambient enclosure temperature T must not be less than 291 K and no more than 295 K during the charging failure period.
- 5.5.9. Procedure of charging failure
- The charging failure is carried out with the on-board charger and consists of the following steps:
- (a) Charging at constant power during t'_1 .
- (b) Charging at maximum current during 30 minutes. During this phase, the on-board charger is blocked at maximum current.
- 5.5.10. The hydrogen analyser must be zeroed and spanned immediately before the end of the test.
- 5.5.11. The end of test period occurs $t'_1 + 30$ minutes after the beginning of the initial sampling, as specified in paragraph 5.8.8. The times elapsed are recorded. The hydrogen concentration, temperature and barometric pressure are measured to give the final readings C_{H_2f} , T_f and P_f for the charging failure test, used for the calculation in paragraph 6.

6. CALCULATION

The hydrogen emission tests described in paragraph 5 allow the calculation of the hydrogen emissions from the normal charge and charging failure phases. Hydrogen emissions from each of these phases are calculated using the initial and final hydrogen concentrations, temperatures and pressures in the enclosure, together with the net enclosure volume.

The formula below is used:

$$M_{H_2} = k \times V \times 10^{-4} \times \left(\frac{\left(1 + \frac{V_{out}}{V}\right) \times C_{H_2f} \times P_f}{T_f} - \frac{C_{H_2i} \times P_i}{T_i} \right)$$

where:

M_{H_2} = hydrogen mass, in grams

C_{H_2} = measured hydrogen concentration in the enclosure, in ppm volume

V = net enclosure volume in cubic metres (m³) corrected for the volume of the vehicle, with the windows and the luggage compartment open. If the volume of the vehicle is not determined a volume of 1.42 m³ is subtracted.

V_{out} = Compensation volume in m³, at the test temperature and pressure

T = ambient chamber temperature, in K

P = absolute enclosure pressure, in kPa

k = 2.42

where: i is the initial reading
 f is the final reading

6.2. Results of test

The hydrogen mass emissions for the vehicle are:

M_N = hydrogen mass emission for normal charge test, in grams

M_D = hydrogen mass emission for charging failure test, in grams

Annex 7 - Appendix 1

CALIBRATION OF EQUIPMENT
FOR HYDROGEN EMISSION TESTING

1. CALIBRATION FREQUENCY AND METHODS

All equipment must be calibrated before its initial use and then calibrated as often as necessary and in any case in the month before type approval testing. The calibration methods to be used are described in this appendix.

2. CALIBRATION OF THE ENCLOSURE

2.1. Initial determination of enclosure internal volume

2.1.1. Before its initial use, the internal volume of the chamber must be determined as follows. The internal dimensions of the chamber are carefully measured, taking into account any irregularities such as bracing struts. The internal volume of the chamber is determined from these measurements.

The enclosure must be latched to a fixed volume when the enclosure is held at an ambient temperature of 293 K. This nominal volume must be repeatable within ± 0.5 per cent of the reported value.

2.1.2. The net internal volume is determined by subtracting 1.42 m³ from the internal volume of the chamber. Alternatively the volume of the test vehicle with the luggage compartment and windows open may be used instead of the 1.42 m³.

2.1.3. The chamber must be checked as in paragraph 2.3. If the hydrogen mass does not agree with the injected mass to within ± 2 per cent then corrective action is required.

2.2. Determination of chamber background emissions

This operation determines that the chamber does not contain any materials that emit significant amounts of hydrogen. The check must be carried out at the enclosure's introduction to service, after any operations in the enclosure which may affect background emissions and at a frequency of at least once per year.

2.2.1. Variable-volume enclosure may be operated in either latched or unlatched volume configuration, as described in paragraph 2.1.1. Ambient temperature must be maintained at 293 K \pm 2 K, throughout the 4-hour period mentioned below.

2.2.2. The enclosure may be sealed and the mixing fan operated for a period of up to 12 hours before the four-hour background-sampling period begins.

- 2.2.3. The analyser (if required) must be calibrated, then zeroed and spanned.
- 2.2.4. The enclosure must be purged until a stable hydrogen reading is obtained, and the mixing fan turned on if not already on.
- 2.2.5. The chamber is then sealed and the background hydrogen concentration, temperature and barometric pressure are measured. These are the initial readings $C_{H_{2i}}$, T_i and P_i used in the enclosure background calculation.
- 2.2.6. The enclosure is allowed to stand undisturbed with the mixing fan on for a period of four hours.
- 2.2.7. At the end of this time the same analyser is used to measure the hydrogen concentration in the chamber. The temperature and the barometric pressure are also measured. These are the final readings $C_{H_{2f}}$, T_f and P_f .
- 2.2.8. The change in mass of hydrogen in the enclosure must be calculated over the time of the test in accordance with paragraph 2.4 and must not exceed 0.5 g.

2.3. Calibration and hydrogen retention test of the chamber

The calibration and hydrogen retention test in the chamber provides a check on the calculated volume (paragraph 2.1) and also measures any leak rate. The enclosure leak rate must be determined at the enclosure's introduction to service, after any operations in the enclosure which may affect the integrity of the enclosure, and at least monthly thereafter. If six consecutive monthly retention checks are successfully completed without corrective action, the enclosure leak rate may be determined quarterly thereafter as long as no corrective action is required.

- 2.3.1. The enclosure must be purged until a stable hydrogen concentration is reached. The mixing fan is turned on, if not already switched on. The hydrogen analyser is zeroed, calibrated if required, and spanned.
- 2.3.2. The enclosure must be latched to the nominal volume position.
- 2.3.3. The ambient temperature control system is then turned on (if not already on) and adjusted for an initial temperature of 293 K.
- 2.3.4. When the enclosure temperature stabilizes at $293\text{ K} \pm 2\text{ K}$, the enclosure is sealed and the background concentration, temperature and barometric pressure measured. These are the initial readings $C_{H_{2i}}$, T_i and P_i used in the enclosure calibration.
- 2.3.5. The enclosure must be unlatched from the nominal volume.

- 2.3.6. A quantity of approximately 100 g of hydrogen is injected into the enclosure. This mass of hydrogen must be measured to an accuracy of ± 2 per cent of the measured value.
- 2.3.7. The contents of the chamber must be allowed to mix for five minutes and then the hydrogen concentration, temperature and barometric pressure are measured. These are the final readings C_{H2f} , T_f and P_f for the calibration of the enclosure as well as the initial readings C_{H2i} , T_i and P_i for the retention check.
- 2.3.8. On the basis of the readings taken in paragraphs 2.3.4 and 2.3.7 and the formula in paragraph 2.4, the mass of hydrogen in the enclosure is calculated. This must be within ± 2 per cent of the mass of hydrogen measured in paragraph 2.3.6.
- 2.3.9. The contents of the chamber must be allowed to mix for a minimum of 10 hours. At the completion of the period, the final hydrogen concentration, temperature and barometric pressure are measured and recorded. These are the final readings C_{H2f} , T_f and P_f for the hydrogen retention check.
- 2.3.10. Using the formula in paragraph 2.4, the hydrogen mass is then calculated from the readings taken in paragraphs 2.3.7 and 2.3.9. This mass may not differ by more than 5 per cent from the hydrogen mass given by paragraph 2.3.8.

2.4. Calculation

The calculation of net hydrogen mass change within the enclosure is used to determine the chamber's hydrocarbon background and leak rate. Initial and final readings of hydrogen concentration, temperature and barometric pressure are used in the following formula to calculate the mass change.

$$M_{H_2} = k \times V \times 10^{-4} \times \left(\frac{\left(1 + \frac{V_{out}}{V}\right) \times C_{H2f} \times P_f}{T_f} - \frac{C_{H2i} \times P_i}{T_i} \right)$$

where:

M_{H_2} = hydrogen mass, in grams

C_{H_2} = measured hydrogen concentration into the enclosure, in ppm volume

V = enclosure volume in cubic metres (m^3) as measured in paragraph 2.1.1.

V_{out} = compensation volume in m^3 , at the test temperature and pressure

T = ambient chamber temperature, in K

P = absolute enclosure pressure, in kPa

k = 2.42

where: i is the initial reading

f is the final reading

3. CALIBRATION OF THE HYDROGEN ANALYZER

The analyzer should be calibrated using hydrogen in air and purified synthetic air. See paragraph 4.8.2. of annex 7.

Each of the normally used operating ranges are calibrated by the following procedure.

- 3.1. Establish the calibration curve by at least five calibration points spaced as evenly as possible over the operating range. The nominal concentration of the calibration gas with the highest concentrations to be at least 80 per cent of the full scale.
- 3.2. Calculate the calibration curve by the method of least squares. If the resulting polynomial degree is greater than 3, then the number of calibration points must be at least the number of the polynomial degree plus 2.
- 3.3. The calibration curve must not differ by more than 2 per cent from the nominal value of each calibration gas.
- 3.4. Using the coefficients of the polynomial derived from paragraph 3.2. above, a table of analyzer readings against true concentrations shall be drawn by steps no greater than 1 per cent of full scale. This is to be carried out for each analyzer range calibrated.

This table shall also contain other relevant data such as:

Date of calibration

Span and zero potentiometer readings (where applicable)

Nominal scale

Reference data of each calibration gas used

The real and indicated value of each calibration gas used together with the percentage differences

Calibration pressure of analyser

- 3.5. Alternative methods (e.g. computer, electronically controlled range switch) can be used if it is proven to the technical service that these methods give equivalent accuracy.

Annex 7 - Appendix 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE FAMILY

1. PARAMETERS DEFINING THE FAMILY RELATIVE TO HYDROGEN EMISSIONS

The family may be defined by basic design parameters which must be common to vehicles within the family. In some cases there may be interaction of parameters. These effects must also be taken into consideration to ensure that only vehicles with similar hydrogen emission characteristics are included within the family.

2. To this end, those vehicle types whose parameters described below are identical are considered to belong to the same hydrogen emissions.

Traction battery:

- Trade name or mark of the battery
- Indication of all types of electro-chemical couples used
- Number of battery cells
- Number of battery modules
- Nominal voltage of the battery (V)
- Battery energy (kWh)
- Gas combination rate (in per cent)
- Type(s) of ventilation for battery module(s) or pack
- Type of cooling system (if any)

On-board charger:

- Make and type of different charger parts
- Output nominal power (kW)
- Maximum voltage of charge (V)

- Maximum intensity of charge (A)
- Make and type of control unit (if any)
- Diagram of operating, controls and safety
- Characteristics of charge periods

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