

21 March 2011

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## 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<sup>1</sup>**

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

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### Addendum 99: Regulation No. 100

#### Revision 1

Incorporating all valid text up to:

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

01 series of amendments to the Regulation - Date of entry into force: 4 December 2010

**Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train**



UNITED NATIONS

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<sup>1</sup> 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.



## Regulation No. 100

### Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train

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## Regulation No. 100

### Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train

#### 1. Scope

The following prescriptions apply to safety requirements with respect to the electric power train of road vehicles of categories M and N, with a maximum design speed exceeding 25 km/h, equipped with one or more traction motor(s) operated by electric power and not permanently connected to the grid, as well as their high voltage components and systems which are galvanically connected to the high voltage bus of the electric power train.

This regulation does not cover post crash safety requirements of road vehicles.

#### 2. Definitions

For the purpose of this regulation the following definitions apply:

- 2.1. "*Active driving possible mode*" means the vehicle mode when application of pressure to the accelerator pedal (or activation of an equivalent control) or release of the brake system will cause the electric power train to move the vehicle.
- 2.2. "*Barrier*" means the part providing protection against direct contact to the live parts from any direction of access.
- 2.3. "*Conductive connection*" means the connection using connectors to an external power supply when the rechargeable energy storage system (RESS) is charged.
- 2.4. "*Coupling system for charging the rechargeable energy storage system (RESS)*" means the electrical circuit used for charging the RESS from an external electric power supply including the vehicle inlet.
- 2.5. "*Direct contact*" means the contact of persons with live parts.
- 2.6. "*Electrical chassis*" means a set made of conductive parts electrically linked together, whose potential is taken as reference.
- 2.7. "*Electrical circuit*" means an assembly of connected live parts which is designed to be electrically energized in normal operation.
- 2.8. "*Electric energy conversion system*" means a system that generates and provides electric energy for electric propulsion.
- 2.9. "*Electric power train*" means the electrical circuit which includes the traction motor(s), and may include the RESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the RESS.
- 2.10. "*Electronic converter*" means a device capable of controlling and/or converting electric power for electric propulsion.

- 2.11. "*Enclosure*" means the part enclosing the internal units and providing protection against direct contact from any direction of access.
- 2.12. "*Exposed conductive part*" means the conductive part which can be touched under the provisions of the protection degree IPXXB, and which becomes electrically energized under isolation failure conditions.
- 2.13. "*External electric power supply*" means an alternating current (AC) or direct current (DC) electric power supply outside of the vehicle.
- 2.14. "*High Voltage*" means the classification of an electric component or circuit, if its working voltage is  $> 60 \text{ V}$  and  $\leq 1500 \text{ V DC}$  or  $> 30 \text{ V}$  and  $\leq 1000 \text{ V AC}$  root mean square (rms).
- 2.15. "*High voltage bus*" means the electrical circuit, including the coupling system for charging the RESS that operates on high voltage.
- 2.16. "*Indirect contact*" means the contact of persons with exposed conductive parts.
- 2.17. "*Live parts*" means the conductive part(s) intended to be electrically energized in normal use.
- 2.18. "*Luggage compartment*" means the space in the vehicle for luggage accommodation, bounded by the roof, hood, floor, side walls, as well as by the barrier and enclosure provided for protecting the power train from direct contact with live parts, being separated from the passenger compartment by the front bulkhead or the rear bulk head.
- 2.19. "*On-board isolation resistance monitoring system*" means the device which monitors the isolation resistance between the high voltage buses and the electrical chassis.
- 2.20. "*Open type traction battery*" means a liquid type battery requiring refilling with water and generating hydrogen gas released to the atmosphere.
- 2.21. "*Passenger compartment*" means the space for occupant accommodation, bounded by the roof, floor, side walls, doors, window glass, front bulkhead and rear bulkhead, or rear gate, as well as by the barriers and enclosures provided for protecting the power train from direct contact with live parts.
- 2.22. "*Protection degree*" means the protection provided by a barrier/enclosure related to the contact with live parts by a test probe, such as a test finger (IPXXB) or a test wire (IPXXD), as defined in Annex 3.
- 2.23. "*Rechargeable energy storage system (RESS)*" means the rechargeable energy storage system that provides electric energy for electric propulsion.
- 2.24. "*Service disconnect*" means the device for deactivation of the electrical circuit when conducting checks and services of the RESS, fuel cell stack, etc.
- 2.25. "*Solid insulator*" means the insulating coating of wiring harnesses provided in order to cover and protect the live parts against direct contact from any direction of access; covers for insulating the live parts of connectors, and varnish or paint for the purpose of insulation.
- 2.26. "*Vehicle type*" means vehicles which do not differ in such essential aspects as:
- (a) Installation of the electric power train and the galvanically connected high voltage bus.

- (b) Nature and type of electric power train and the galvanically connected high voltage components.
- 2.27. "Working voltage" means the highest value of an electrical circuit voltage root-mean-square (rms), specified by the manufacturer, which may occur between any conductive parts in open circuit conditions or under normal operating condition. If the electrical circuit is divided by galvanic isolation, the working voltage is defined for each divided circuit, respectively.

### **3. Application for approval**

- 3.1. The application for approval of a vehicle type with regard to specific requirements for the electric power train shall be submitted by vehicle manufacturer or by his duly accredited representative.
- 3.2. It shall be accompanied by the under-mentioned documents in triplicate and following particulars:
  - 3.2.1. Detailed description of the vehicle type as regards the electric power train and the galvanically connected high voltage bus.
- 3.3. A vehicle representative of the vehicle type to be approved shall be submitted to the technical service responsible for conducting the approval tests.
- 3.4. The competent Authority shall verify the existence of satisfactory arrangements for ensuring effective control of the conformity of production before type approval is granted.

### **4. Approval**

- 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.
- 4.2. An approval number shall be assigned to each type approved. Its first two digits (at present 01 for the Regulation in its form) shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval. The same Contracting Party shall not assign the same number to another vehicle type.
- 4.3. Notice of approval or of refusal or of extension or withdrawal of approval or production definitely discontinued of a vehicle type pursuant to this Regulation shall be communicated to the Parties to the Agreement applying this Regulation, by means of a form conforming to the model in Annex 1 to this Regulation.
- 4.4. There shall be affixed, conspicuously and in a readily accessible place specified on the approval form, to every vehicle conforming to a vehicle type approved under this Regulation an international approval mark consisting of:

- 4.4.1. A circle surrounding the Letter "E" followed by the distinguishing number of the country which has granted approval<sup>1</sup>.
- 4.4.2. The number of this Regulation, followed by the Letter "R", a dash and the approval number to the right of the circle described in paragraph 4.4.1.
- 4.5. If the vehicle conforms to a vehicle type approved under one or more other Regulations annexed to the Agreement in the country which has granted approval under this Regulation, the symbol prescribed in paragraph 4.4.1. need not be repeated; in this case the Regulation and approval numbers and the additional symbols of all the Regulations under which approval has been granted in the country which has granted approval under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in paragraph 4.4.1.
- 4.6. The approval mark shall be clearly legible and shall be indelible.
- 4.7. The approval mark shall be placed on or close to the vehicle data plate affixed by the Manufacturer.
- 4.8. Annex 2 to this Regulation gives examples of the arrangements of the approval mark.

## **5. Specifications and tests**

### **5.1. Protection against electrical shock**

These electrical safety requirements apply to high voltage buses under conditions where they are not connected to external high voltage power supplies.

#### **5.1.1. Protection against direct contact**

The protection against direct contact with live parts shall comply with paragraphs 5.1.1.1. and 5.1.1.2. These protections (solid insulator, barrier, enclosure, etc.) shall not be able to be opened, disassembled or removed without the use of tools.

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<sup>1</sup> 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 Serbia, 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 (Kazakhstan), 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 Union (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, 48 for New Zealand, 49 for Cyprus, 50 for Malta, 51 for the Republic of Korea, 52 for Malaysia, 53 for Thailand, 54 and 55 (vacant), 56 for Montenegro, 57 (vacant) and 58 for Tunisia. Other 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.

- 5.1.1.1. For protection of live parts inside the passenger compartment or luggage compartment, the protection degree IPXXD shall be provided.
- 5.1.1.2. For protection of live parts in areas other than the passenger compartment or luggage compartment, the protection degree IPXXB shall be satisfied.
- 5.1.1.3. Connectors  
Connectors (including vehicle inlet) are deemed to meet this requirement if:
  - (a) They comply with 5.1.1.1. and 5.1.1.2. when separated without the use of tools, or
  - (b) They are located underneath the floor and are provided with a locking mechanism, or
  - (c) They are provided with a locking mechanism and other components shall be removed with the use of tools in order to separate the connector, or
  - (d) The voltage of the live parts becomes equal or below DC 60V or equal or below AC 30V (rms) within one second after the connector is separated.
- 5.1.1.4. Service disconnect  
For a service disconnect which can be opened, disassembled or removed without tools, it is acceptable if protection degree IPXXB is satisfied under a condition where it is opened, disassembled or removed without tools.
- 5.1.1.5. Marking
- 5.1.1.5.1. The symbol shown in Figure 1 shall appear on or near the RESS. The symbol background shall be yellow, the bordering and the arrow shall be black.

Figure 1  
**Marking of high voltage equipment**



- 5.1.1.5.2. The symbol shall also be visible on enclosures and barriers, which, when removed expose live parts of high voltage circuits. This provision is optional to any connector for high voltage buses. This provision shall not apply to any of the following cases:
  - (a) Where barriers or enclosures cannot be physically accessed, opened, or removed; unless other vehicle components are removed with the use of tools;
  - (b) Where barriers or enclosures are located underneath the vehicle floor.
- 5.1.1.5.3. Cables for high voltage buses which are not located within enclosures shall be identified by having an outer covering with the colour orange.
- 5.1.2. *Protection against indirect contact*
- 5.1.2.1. For protection against electrical shock which could arise from indirect contact, the exposed conductive parts, such as the conductive barrier and

- enclosure, shall be galvanically connected securely to the electrical chassis by connection with electrical wire or ground cable, or by welding, or by connection using bolts, etc. so that no dangerous potentials are produced.
- 5.1.2.2. The resistance between all exposed conductive parts and the electrical chassis shall be lower than 0.1 ohm when there is current flow of at least 0.2 amperes.
- This requirement is satisfied if the galvanic connection has been established by welding.
- 5.1.2.3. In the case of motor vehicles which are intended to be connected to the grounded external electric power supply through the conductive connection, a device to enable the galvanical connection of the electrical chassis to the earth ground shall be provided.
- The device should enable connection to the earth ground before exterior voltage is applied to the vehicle and retain the connection until after the exterior voltage is removed from the vehicle.
- Compliance to this requirement may be demonstrated either by using the connector specified by the car manufacturer, or by analysis.
- 5.1.3. *Isolation resistance*
- 5.1.3.1. Electric power train consisting of separate Direct Current- or Alternating Current-buses
- If AC high voltage buses and DC high voltage buses are galvanically isolated from each other, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100  $\Omega$ /volt of the working voltage for DC buses, and a minimum value of 500  $\Omega$ /volt of the working voltage for AC buses.
- The measurement shall be conducted according to Annex 4 "Isolation resistance measurement method".
- 5.1.3.2. Electric power train consisting of combined DC- and AC-buses
- If AC high voltage buses and DC high voltage buses are galvanically connected isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 500  $\Omega$ /volt of the working voltage.
- However, if all AC high voltage buses are protected by one of the 2 following measures, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100  $\Omega$ /V of the working voltage:
- (a) Double or more layers of solid insulators, barriers or enclosures that meet the requirement in paragraph 5.1.1. independently, for example wiring harness;
  - (b) Mechanically robust protections that have sufficient durability over vehicle service life such as motor housings, electronic converter cases or connectors;
- The isolation resistance between the high voltage bus and the electrical chassis may be demonstrated by calculation, measurement or a combination of both.

The measurement shall be conducted according to Annex 4 "Isolation resistance measurement method".

5.1.3.3. Fuel cell vehicles

If the minimum isolation resistance requirement cannot be maintained over time, then protection shall be achieved by any of the following:

- (a) Double or more layers of solid insulators, barriers or enclosures that meet the requirement in paragraph 5.1.1. independently;
- (b) On-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value. The isolation resistance between the high voltage bus of the coupling system for charging the RESS, which is not energized besides during charging the RESS, and the electrical chassis need not be monitored. The function of the on-board isolation resistance monitoring system shall be confirmed as described in Annex 5.

5.1.3.4. Isolation resistance requirement for the coupling system for charging the RESS

For the vehicle inlet intended to be conductively connected to the grounded external AC power supply and the electrical circuit that is galvanically connected to the vehicle inlet during charging of the RESS, the isolation resistance between the high voltage bus and the electrical chassis shall be at least 1 MΩ when the charger coupler is disconnected. During the measurement, the traction battery may be disconnected.

**5.2. Rechargeable energy storage system (RESS)**

5.2.1. *Protection against excessive current*

The RESS shall not overheat.

If the RESS is subject to overheating due to excessive current, it shall be equipped with a protective device such as fuses, circuit breakers or main contactors.

However, the requirement may not apply if the manufacturer supplies data that ensure that overheating from excessive current is prevented without the protective device.

5.2.2. *Accumulation of gas*

Places for containing open type traction battery that may produce hydrogen gas shall be provided with a ventilation fan or a ventilation duct to prevent the accumulation of hydrogen gas.

**5.3. Functional safety**

At least a momentary indication shall be given to the driver when the vehicle is in "active driving possible mode".

However, this provision does not apply under conditions where an internal combustion engine provides directly or indirectly the vehicle's propulsion power.

When leaving the vehicle, the driver shall be informed by a signal (e.g. optical or audible signal) if the vehicle is still in the active driving possible mode.

If the on-board RESS can be externally charged by the user, vehicle movement by its own propulsion system shall be impossible as long as the connector of the external electric power supply is physically connected to the vehicle inlet.

This requirement shall be demonstrated by using the connector specified by the car manufacturer.

The state of the drive direction control unit shall be identified to the driver.

#### **5.4. Determination of hydrogen emissions**

- 5.4.1. This test shall be carried out on all vehicles equipped with open type traction batteries.
- 5.4.2. The test shall be conducted following the method described in Annex 7 to the present Regulation. The hydrogen sampling and analysis shall be the ones prescribed. Other analysis methods can be approved if it is proven that they give equivalent results.
- 5.4.3. During a normal charge procedure in the conditions given in Annex 7, hydrogen emissions shall be below 125 g during 5 h, or below  $25 \times t_2$  g during  $t_2$  (in h).
- 5.4.4. During a charge carried out by an on-board charger presenting a failure (conditions given in Annex 7), hydrogen emissions shall be below 42 g. Furthermore the on-board charger shall limit this possible failure to 30 minutes.
- 5.4.5. All the operations linked to the battery charging are controlled automatically, included the stop for charging.
- 5.4.6. It shall not be possible to take a manual control of the charging phases.
- 5.4.7. Normal operations of connection and disconnection to the mains or power cuts shall not affect the control system of the charging phases.
- 5.4.8. Important charging failures shall 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.
- 5.4.9. The manufacturer has to indicate in the owner's manual, the conformity of the vehicle to these requirements.
- 5.4.10. 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.

#### **6. Modification and extension of the type approval for vehicle type**

- 6.1. Every modification of the vehicle type shall be notified to the administrative department which approved the vehicle type. The department may then either:

- 6.1.1. Consider that the modifications made are unlikely to have an appreciable adverse effect and that in any case the vehicle still complies with the requirements, or
- 6.1.2. Require a further test report from the technical service responsible for conducting the tests.
- 6.2. Confirmation or refusal of approval, specifying the alteration, shall be communicated by the procedure specified in paragraph 4.3. above to the Parties to the Agreement applying this Regulation.
- 6.3. The competent Authority issuing the extension of approval shall assign a series number for such an extension and inform thereof the other Parties to the 1958 Agreement applying the Regulation by means of a communication form conforming to the model in Annex 1 to this Regulation.

## **7. Conformity of production**

- 7.1. Every vehicle approved under this Regulation shall be so manufactured as to conform to the type approved by meeting the requirements set out in paragraph 5. above.
- 7.2. In order to verify that the requirements of paragraph 7.1 are met, suitable controls of the production shall be carried out.
- 7.3. The holder of the approval shall, in particular:
  - 7.3.1. Ensure the existence of procedures for the effective quality control of vehicles;
  - 7.3.2. Have access to the testing equipment necessary for checking the conformity of each approved type;
  - 7.3.3. Ensure that test result data are recorded and that the annexed documents remain available for a period to be determined in agreement with the administrative department;
  - 7.3.4. Analyse the results of each type of test, in order to verify and ensure the consistency of characteristics of the vehicle, making allowance for permissible variations in industrial production;
  - 7.3.5. Ensure that for each type of vehicle at least the tests prescribed in paragraph 5 of this Regulation are carried out;
  - 7.3.6. Ensure that any set of samples or test pieces giving evidence of non-conformity with the type of test in question shall give rise to a further sampling and test. All necessary steps shall be taken to re-establish conformity of the corresponding production.
- 7.4. The competent Authority which has granted type approval may at any time verify the conformity control methods applied in each production unit.
  - 7.4.1. At every inspection, the test records and production records shall be presented to the visiting inspector.
  - 7.4.2. The inspector may take samples at random to be tested in the manufacturer's laboratory. The minimum number of samples may be determined according to the results of the manufacturer's own checks.

- 7.4.3. When the quality level appears unsatisfactory or when it seems necessary to verify the validity of the tests carried out in application of paragraph 7.4.2., the inspector shall select samples to be sent to the technical service which has conducted the type approval tests.
- 7.4.4. The competent Authority may carry out any test prescribed in this Regulation.
- 7.4.5. The normal frequency of inspections by the competent Authority shall be one per year. If unsatisfactory results are recorded during one of these visits, the competent Authority shall ensure that all necessary steps are taken to re-establish the conformity of production as rapidly as possible.

## **8. Penalties for non-conformity of production**

- 8.1. The approval granted in respect of a vehicle type, pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 7. above are not complied with, or if the vehicle or its components fail to pass the tests provided for in paragraph 7.3.5. above.
- 8.2. If a Contracting Party to the Agreement applying this Regulation withdraws an approval it has previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation, by means of a communication form conforming to the Model in Annex 1 to this Regulation.

## **9. Production definitely discontinued**

If the holder of the approval completely ceases to manufacture a type of vehicle approved in accordance with this Regulation, he shall so inform the Authority which granted the approval. Upon receiving the relevant communication, that Authority shall inform thereof the other Contracting Parties to the 1958 Agreement applying this Regulation by means of a communication form conforming to the model in Annex 1 to this Regulation.

## **10. Names and addresses of technical services responsible for conducting approval tests and of administrative departments**

The Contracting Parties to the 1958 Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the technical services responsible for conducting approval tests and the administrative departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval or production definitely discontinued, issued in other countries are to be sent.

## **11. Transitional provisions**

- 11.1. As from the official date of entry into force of the 01 series of amendments, no Contracting Party applying this Regulation shall refuse to grant approval under this Regulation as amended by the 01 series of amendments.

- 11.2. As from 24 months after the date of entry into force, Contracting Parties applying this Regulation shall grant approvals only if the vehicle type to be approved meets the requirements of this Regulation as amended by the 01 series of amendments.
- 11.3. Contracting Parties applying this Regulation shall not refuse to grant extensions of approval to the preceding series of amendments to this Regulation.
- 11.4. Contracting Parties applying this Regulation shall continue to grant approvals to those types of vehicles which comply with the requirements of this Regulation as amended by the preceding series of amendments during the 24 months' period which follows the date of entry into force of the 01 series of amendments.
- 11.5. Notwithstanding the transitional provisions above, Contracting Parties whose application of this Regulation comes into force after the date of entry into force of the most recent series of amendments are not obliged to accept approvals which were granted in accordance with any of the preceding series of amendments to this Regulation.

## Annex 1

### Communication

(maximum format: A4 (210 x 297 mm))



Issued by:

Name of administration:

.....  
.....  
.....  
.....

Concerning<sup>2</sup>: APPROVAL GRANTED,  
APPROVAL EXTENDED,  
APPROVAL REFUSED,  
APPROVAL WITHDRAWN,  
APPROVAL DEFINITELY DISCONTINUED,

of a road vehicle pursuant to Regulation No. 100

Approval No. .... Extension No. ....

1. Trade name or mark of the vehicle: .....
2. Vehicle type: .....
3. Vehicle category: .....
4. Manufacturer's name and address: .....  
.....
5. If applicable, name and address of manufacturer's representative: .....  
.....
6. Description of the vehicle: .....
- 6.1. RESS type: .....
- 6.2. Working voltage: .....
- 6.3. Propulsion system (e.g. hybrid, electric): .....
7. Vehicle submitted for approval on: .....

<sup>1</sup> Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

<sup>2</sup> Strike out what does not apply.

8. Technical service responsible for conducting approval tests: .....  
.....
9. Date of report issued by that service: .....
10. Number of report issued by that service: .....
11. Location of the approval mark: .....
12. Reason(s) for extension of approval (if applicable)<sup>2</sup>: .....
13. Approval granted/extended/refused/withdrawn<sup>2</sup>: .....
14. Place: .....
15. Date: .....
16. Signature: .....
17. The documents filed with the request for approval or extension may be obtained on request.

Annex 2

Arrangements of approval marks

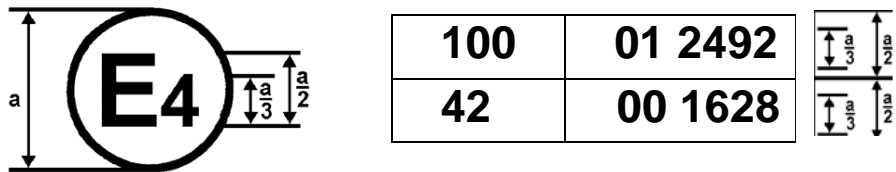
Model A  
(see paragraph 4.4. of this Regulation)



a = 8 mm min.

The above approval mark affixed to a vehicle shows that the road vehicle type concerned has been approved in the Netherlands (E4), pursuant to Regulation No. 100, and under the approval number 012492. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. 100 as amended by 01 series of amendments.

Model B  
(see paragraph 4.5. of this Regulation)



a = 8 mm min.

The above approval mark affixed to a vehicle shows that the road vehicle concerned has been approved in the Netherlands (E4) pursuant to Regulations Nos. 100 and 42\*. The approval number indicates that, at the dates when the respective approvals were granted, Regulation No. 100 was amended by the 01 series of amendments and Regulation No. 42 was still in its original form.

\* The latter number is given only as an example.

## Annex 3

### Protection against direct contacts of parts under voltage

1. Access probes  
Access probes to verify the protection of persons against access to live parts are given in Table 1.
2. Test conditions  
The access probe is pushed against any openings of the enclosure with the force specified in Table 1. If it partly or fully penetrates, it is placed in every possible position, but in no case shall the stop face fully penetrate through the opening.  
Internal barriers are considered part of the enclosure  
A low-voltage supply (of not less than 40 V and not more than 50 V) in series with a suitable lamp should be connected, if necessary, between the probe and live parts inside the barrier or enclosure.  
The signal-circuit method should also be applied to the moving live parts of high voltage equipment.  
Internal moving parts may be operated slowly, where this is possible.
3. Acceptance conditions  
The access probe shall not touch live parts.  
If this requirement is verified by a signal circuit between the probe and live parts, the lamp shall not light.  
In the case of the test for IPXXB, the jointed test finger may penetrate to its 80 mm length, but the stop face (diameter 50 mm x 20 mm) shall not pass through the opening. Starting from the straight position, both joints of the test finger shall be successively bent through an angle of up to 90 degree with respect to the axis of the adjoining section of the finger and shall be placed in every possible position.  
In case of the tests for IPXXD, the access probe may penetrate to its full length, but the stop face shall not fully penetrate through the opening.

Table 1

Access probes for the tests for protection of persons against access to hazardous parts

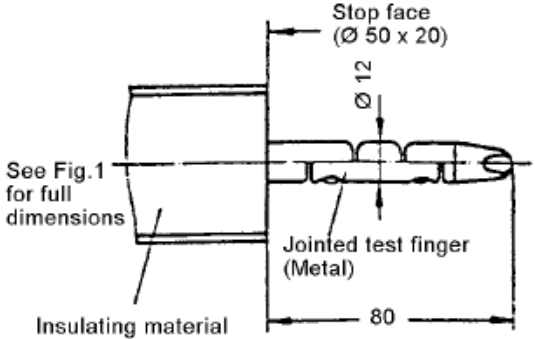
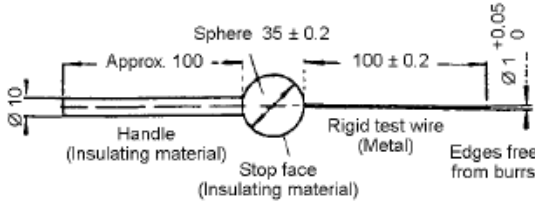
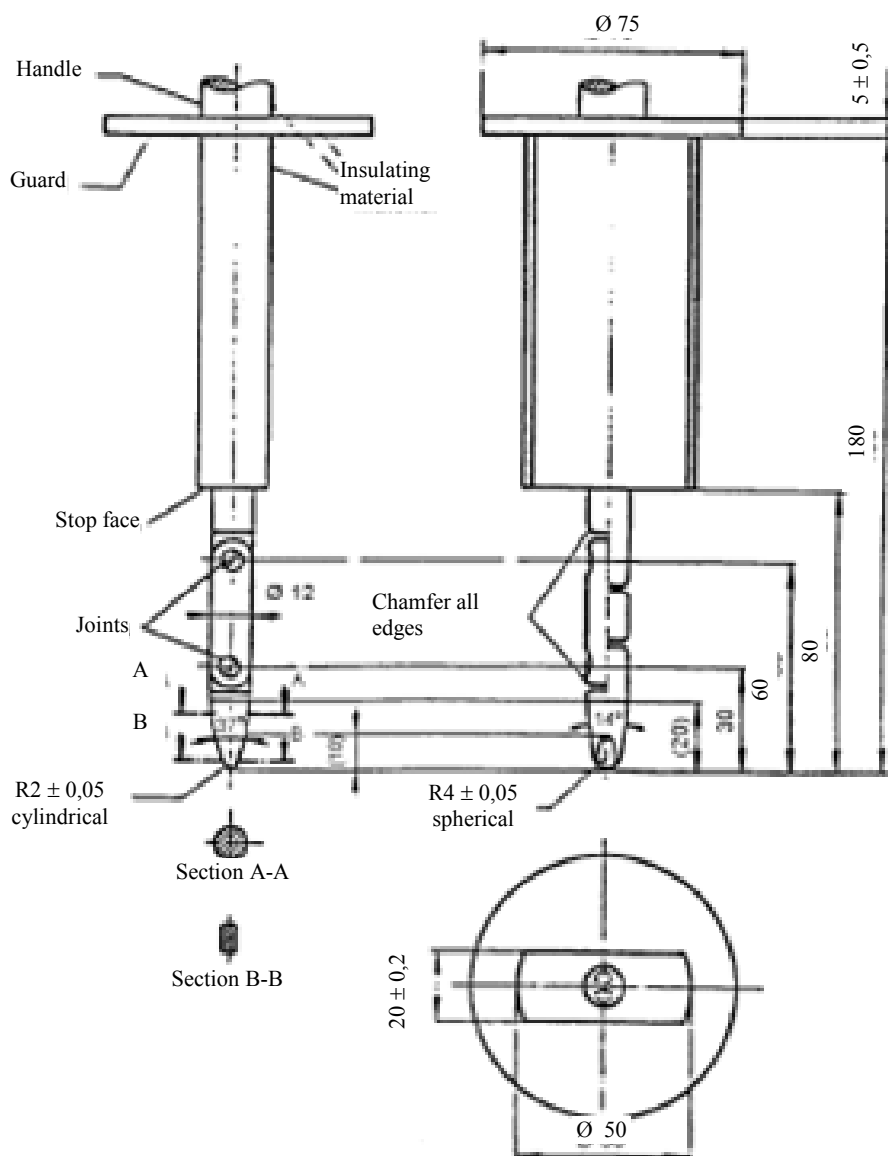
First numeral	Addit. letter	Access probe (Dimensions in mm)	Test force
2	B	<p><b>Jointed test finger</b></p>  <p>See Fig. 1 for full dimensions</p> <p>Insulating material</p> <p>Stop face (Ø 50 x 20)</p> <p>Ø 12</p> <p>Jointed test finger (Metal)</p> <p>80</p>	10 N ± 10 %
4, 5, 6	D	<p><b>Test wire 1.0 mm diameter, 100 mm long</b></p>  <p>Ø 10</p> <p>Approx. 100</p> <p>Sphere 35 ± 0.2</p> <p>100 ± 0.2</p> <p>Ø 1.0 +0.05 0</p> <p>Handle (Insulating material)</p> <p>Stop face (Insulating material)</p> <p>Rigid test wire (Metal)</p> <p>Edges free from burrs</p>	1 N ± 10 %

Figure 1  
**Jointed test finger**



Material: metal, except where otherwise specified

Linear dimensions in millimeters

Tolerances on dimensions without specific tolerance:

- (a) Nn angles: 0/-10°;
- (b) On linear dimensions: up to 25 mm: 0/-0.05 mm over 25 mm:  $\pm 0.2$  mm

Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a 0 to +10° tolerance.

## Annex 4

### Isolation resistance measurement method

#### 1. General

The isolation resistance for each high voltage bus of the vehicle shall be measured or shall be determined by calculation using measurement values from each part or component unit of a high voltage bus (hereinafter referred to as the "divided measurement").

#### 2. Measurement method

The isolation resistance measurement shall be conducted by selecting an appropriate measurement method from among those listed in paragraphs 2.1. through 2.2., depending on the electrical charge of the live parts or the isolation resistance, etc.

The range of the electrical circuit to be measured shall be clarified in advance, using electrical circuit diagrams, etc.

Moreover, modification necessary for measuring the isolation resistance may be carried out, such as removal of the cover in order to reach the live parts, drawing of measurement lines, change in software, etc.

In cases where the measured values are not stable due to the operation of the on-board isolation resistance monitoring system, etc., necessary modification for conducting the measurement may be carried out, such as stopping of the operation of the device concerned or removing it. Furthermore, when the device is removed, it shall be proven, using drawings, etc., that it will not change the isolation resistance between the live parts and the electrical chassis.

Utmost care shall be exercised as to short circuit, electric shock, etc., for this confirmation might require direct operations of the high-voltage circuit.

#### 2.1. Measurement method using DC voltage from off-vehicle sources

##### 2.1.1. Measurement instrument

An isolation resistance test instrument capable of applying a DC voltage higher than the working voltage of the high voltage bus shall be used.

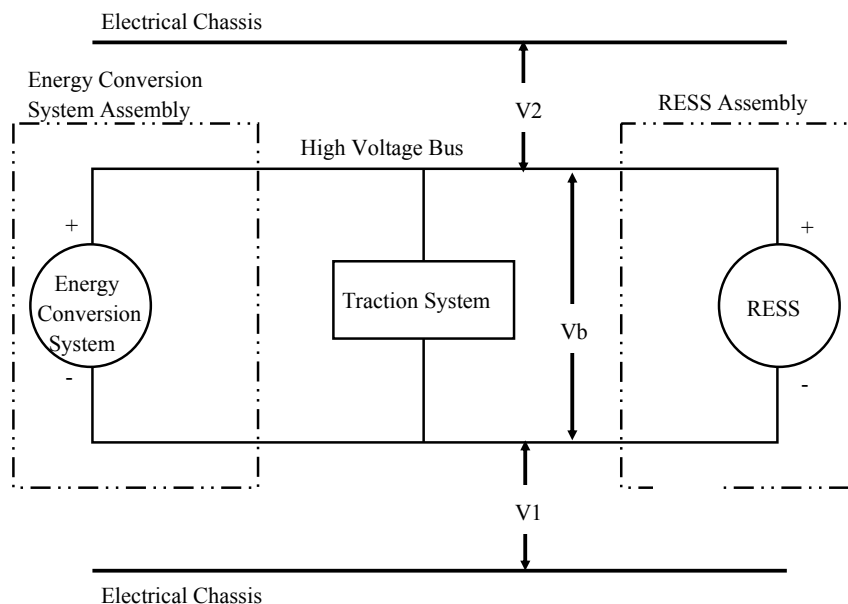
##### 2.1.2. Measurement method

An insulator resistance test instrument shall be connected between the live parts and the electrical chassis. Then, the isolation resistance shall be measured by applying a DC voltage at least half of the working voltage of the high voltage bus.

If the system has several voltage ranges (e.g. because of boost converter) in galvanically connected circuit and some of the components cannot withstand the working voltage of the entire circuit, the isolation resistance between those components and the electrical chassis can be measured separately by applying at least half of their own working voltage with those component disconnected.

- 2.2. Measurement method using the vehicle's own RESS as DC voltage source
- 2.2.1. Test vehicle conditions
- The high voltage-bus shall be energized by the vehicle's own RESS and/or energy conversion system and the voltage level of the RESS and/or energy conversion system throughout the test shall be at least the nominal operating voltage as specified by the vehicle manufacturer.
- 2.2.2. Measurement instrument
- The voltmeter used in this test shall measure DC values and shall have an internal resistance of at least 10 MΩ.
- 2.2.3. Measurement method
- 2.2.3.1. First step
- The voltage is measured as shown in Figure 1 and the high voltage bus voltage ( $V_b$ ) is recorded.  $V_b$  shall be equal to or greater than the nominal operating voltage of the RESS and/or energy conversion system as specified by the vehicle manufacturer.

Figure 1  
**Measurement of  $V_b$ ,  $V_1$ ,  $V_2$**



- 2.2.3.2. Second step
- Measure and record the voltage ( $V_1$ ) between the negative side of the high voltage bus and the electrical chassis (see Figure 1).
- 2.2.3.3. Third step
- Measure and record the voltage ( $V_2$ ) between the positive side of the high voltage bus and the electrical chassis (see Figure 1).

2.2.3.4. Fourth step

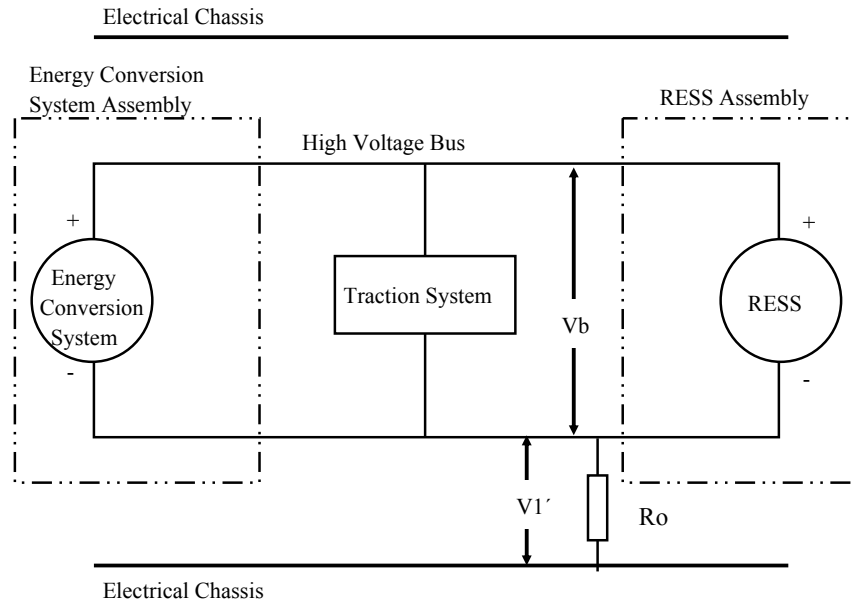
If V1 is greater than or equal to V2, insert a standard known resistance (Ro) between the negative side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage (V1') between the negative side of the high voltage bus and the electrical chassis (see Figure 2).

Calculate the electrical isolation (Ri) according to the following formula:

$$R_i = R_o \cdot (V_b / V1' - V_b / V1) \quad \text{or} \quad R_i = R_o \cdot V_b \cdot (1 / V1' - 1 / V1)$$

Figure 2

**Measurement of V1'**

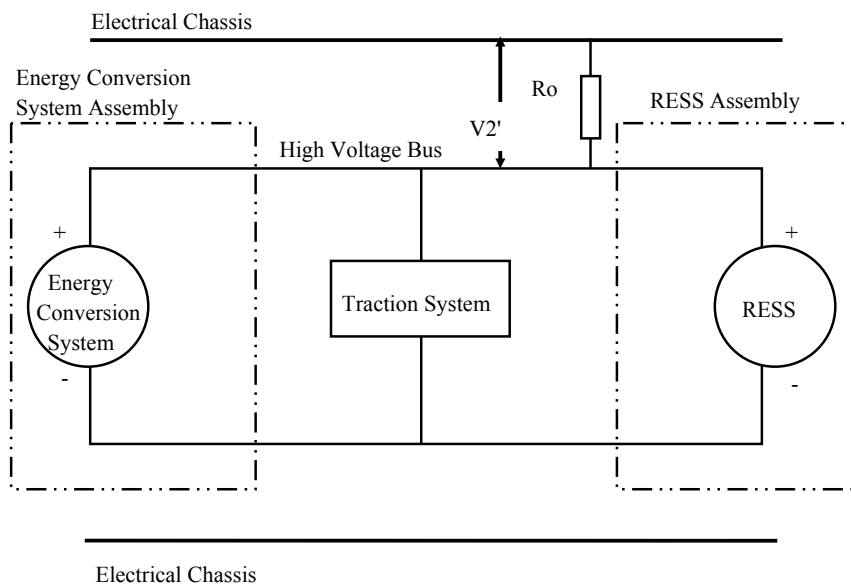


If V2 is greater than V1, insert a standard known resistance (Ro) between the positive side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage (V2') between the positive side of the high voltage bus and the electrical chassis (see Figure 3). Calculate the electrical isolation (Ri) according to the formula shown. Divide this electrical isolation value (in  $\Omega$ ) by the nominal operating voltage of the high voltage bus (in volts).

Calculate the electrical isolation (Ri) according to the following formula:

$$R_i = R_o \cdot (V_b / V2' - V_b / V2) \quad \text{or} \quad R_i = R_o \cdot V_b \cdot (1 / V2' - 1 / V2)$$

Figure 3  
Measurement of  $V_2'$



2.2.3.5. Fifth step

The electrical isolation value  $R_i$  (in  $\Omega$ ) divided by the working voltage of the high voltage bus (in volts) results in the isolation resistance (in  $\Omega/V$ ).

*Note:* The standard known resistance  $R_o$  (in  $\Omega$ ) should be the value of the minimum required isolation resistance (in  $\Omega/V$ ) multiplied by the working voltage of the vehicle plus/minus 20 per cent (in volts).  $R_o$  is not required to be precisely this value since the equations are valid for any  $R_o$ ; however, a  $R_o$  value in this range should provide good resolution for the voltage measurements.

## **Annex 5**

### **Confirmation method for function of on-board isolation resistance monitoring system**

The function of the on-board isolation resistance monitoring system shall be confirmed by the following method:

Insert a resistor that does not cause the isolation resistance between the terminal being monitored and the electrical chassis to drop below the minimum required isolation resistance value. The warning shall be activated.

## Annex 6

### Essential characteristics of road vehicles or systems

1. General
  - 1.1. Make (trade name of manufacturer): .....
  - 1.2. Type: .....
  - 1.3. Vehicle category: .....
  - 1.4. Commercial name(s) if available: .....  
.....
  - 1.5. Manufacturer's name and address: .....  
.....
  - 1.6. If applicable, name and address of manufacturer's representative: .....  
.....
  - 1.7. Drawing and/or photograph of the vehicle: .....
2. Electric motor (traction motor)
  - 2.1. Type (winding, excitation): .....
  - 2.2. Maximum hourly output (kW): .....
3. Battery (if RESS is battery)
  - 3.1. Trade name and mark of the battery: .....
  - 3.2. Indication of all types of electro-chemical cells: .....
  - 3.3. Nominal voltage (V): .....
  - 3.4. Number of battery cells: .....
  - 3.5. Gas combination rate (in per cent): .....
  - 3.6. Type(s) of ventilation for battery module/pack: .....
  - 3.7. Type of cooling system (if any): .....
  - 3.8. Capacity (Ah): .....

4. Fuel Cell (if any)
  - 4.1. Trade name and mark of the fuel cell: .....  
.....
  - 4.2. Types of fuel cell: .....
  - 4.3. Nominal voltage (V): .....
  - 4.4. Number of cells: .....
  - 4.5. Type of cooling system (if any): .....
  - 4.6. Max Power(kW): .....
5. Fuse and/or circuit breaker
  - 5.1. Type: .....
  - 5.2. Diagram showing the functional range: .....
6. Power wiring harness
  - 6.1. Type: .....
7. Protection against Electric Shock
  - 7.1. Description of the protection concept: .....
8. Additional data
  - 8.1. Brief description of the power circuit components installation or drawings/  
pictures showing the location of the power circuit components installation: .....
  - 8.2. Schematic diagram of all electrical functions included in power circuit: .....
  - 8.3. Working voltage (V): .....

## 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 road vehicles, according to paragraph 5.4. of this Regulation.

2. Description of test

The hydrogen emission test (Figure 1 of the present annex) 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.

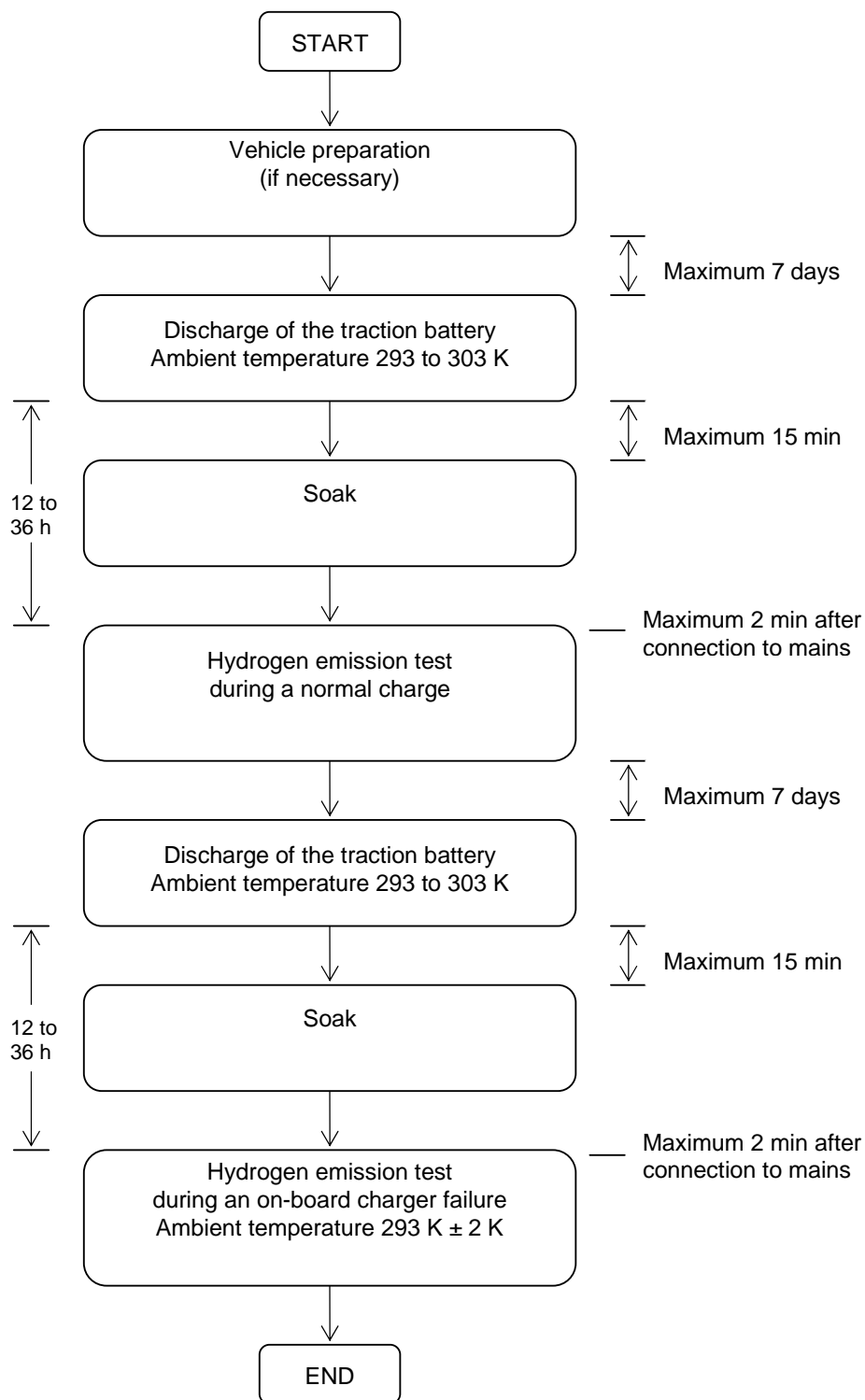
3. Vehicle

3.1. The vehicle shall be in good mechanical condition and have been driven at 300 km during seven days before the test. The vehicle shall 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 shall follow the manufacturer's procedure in order to keep the traction battery temperature in normal functioning range.

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

Figure 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 shall meet the requirements of the 05 series of amendments to Regulation No. 83.
- 4.2. Hydrogen emission measurement enclosure

The hydrogen emission measurement enclosure shall be a gas-tight measuring chamber able to contain the vehicle under test. The vehicle shall be accessible from all sides and the enclosure when sealed shall be gas-tight in accordance with Appendix 1 to this annex. The inner surface of the enclosure shall be impermeable and non-reactive to hydrogen. The temperature conditioning system shall be capable of controlling the internal enclosure air temperature to follow the prescribed temperature throughout the test, with an average tolerance of  $\pm 2$  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 shall maintain the integrity of the enclosure as specified in Appendix 1 to this annex.

Any method of volume accommodation shall limit the differential between the enclosure internal pressure and the barometric pressure to a maximum value of  $\pm 5$  hPa.

The enclosure shall be capable of latching to a fixed volume. A variable volume enclosure shall 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 shall be drawn from the mid-point of one side-wall or roof of the chamber and any bypass flow shall be returned to the enclosure, preferably to a point immediately downstream of the mixing fan.
- 4.3.1.2. The hydrogen analyser shall have a response time to 90 per cent of final reading of less than 10 seconds. Its stability shall 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 shall 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 shall 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 shall be fitted with a device to record electrical signal output, at a frequency of at least once per minute. The recording system shall have operating characteristics at least equivalent to the signal being recorded and shall provide a permanent record of results. The recording shall 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  $0.9 \pm 0.2$  m.
- 4.4.2. The temperatures of the battery modules are recorded by means of the sensors.
- 4.4.3. Temperatures shall, 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 shall be within  $\pm 1.0$  K and the temperature shall be capable of being resolved to  $\pm 0.1$  K.
- 4.4.5. The recording or data processing system shall be capable of resolving time to  $\pm 15$  seconds.
- 4.5. Pressure recording
- 4.5.1. The difference  $\Delta p$  between barometric pressure within the test area and the enclosure internal pressure shall, 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 shall be within  $\pm 2$  hPa and the pressure shall be capable of being resolved to  $\pm 0.2$  hPa.
- 4.5.3. The recording or data processing system shall be capable of resolving time to  $\pm 15$  seconds.
- 4.6. Voltage and current intensity recording
- 4.6.1. The on-board charger voltage and current intensity (battery) shall, 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 shall be within  $\pm 1$  V and the voltage shall be capable of being resolved to  $\pm 0.1$  V.
- 4.6.3. The accuracy of the current intensity recording system shall be within  $\pm 0.5$  A and the current intensity shall be capable of being resolved to  $\pm 0.05$  A.
- 4.6.4. The recording or data processing system shall be capable of resolving time to  $\pm 15$  seconds.

4.7. Fans

The chamber shall be equipped with one or more fans or blowers with a possible flow of 0.1 to 0.5 m<sup>3</sup>/second in order to thoroughly mix the atmosphere in the enclosure. It shall be possible to reach a homogeneous temperature and hydrogen concentration in the chamber during measurements. The vehicle in the enclosure shall not be subjected to a direct stream of air from the fans or blowers.

4.8. Gases

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

- (a) Purified synthetic air (purity < 1 ppm C<sub>1</sub> equivalent; < 1 ppm CO; < 400 ppm CO<sub>2</sub>; < 0.1 ppm NO ); oxygen content between 18 and 21 per cent by volume,
- (b) Hydrogen ( H<sub>2</sub> ), 99.5 per cent minimum purity.

4.8.2. Calibration and span gases shall contain mixtures of hydrogen (H<sub>2</sub>) and purified synthetic air. The real concentrations of a calibration gas shall be within ±2 per cent of the nominal values. The accuracy of the diluted gases obtained when using a gas divider shall 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:

- (a) Vehicle preparation;
- (b) Discharge of the traction battery;
- (c) Determination of hydrogen emissions during a normal charge;
- (d) Discharge of the traction battery;
- (e) 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 shall be checked, proving that the vehicle has performed at least 300 km during seven days before the test. During this period, the vehicle shall 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 ± 5 per cent of the maximum speed of the vehicle during 30 minutes.

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.
- 5.1.2. 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. and 5.1.2. shall 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 paragraph 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 shall be soaked at  $293\text{ K} \pm 2\text{ K}$ .
- 5.4. Hydrogen emission test during a normal charge
  - 5.4.1. Before the completion of the soak period, the measuring chamber shall be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.
  - 5.4.2. The hydrogen analyser shall 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 shall be moved into the measuring chamber.
  - 5.4.4. 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  $C_{H_2i}$ ,  $T_i$  and  $P_i$  for the normal charge test.
- These figures are used in the hydrogen emission calculation (paragraph 6.). The ambient enclosure temperature  $T$  shall 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 shall 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  $t_1 + 5$  hours 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  $C_{H_2f}$ ,  $T_f$  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. shall be repeated.
- 5.5.3. Before the completion of the soak period, the measuring chamber shall be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.
- 5.5.4. The hydrogen analyser shall 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 shall 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  $C_{H2i}$ ,  $T_i$  and  $P_i$  for the failure charge test.
- These figures are used in the hydrogen emission calculation (paragraph 6). The ambient enclosure temperature  $T$  shall 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 shall 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 5.5.8. The 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 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:

$$M_{H2} = k \times V \times 10^{-4} \times \left( \frac{\left(1 + \frac{V_{out}}{V}\right) \times C_{H2f} \times P_f}{T_f} - \frac{C_{H2i} \times P_i}{T_i} \right)$$

where:

- $M_{H2}$  = hydrogen mass, in grams
- $C_{H2}$  = measured hydrogen concentration in the enclosure, in ppm volume
- $V$  = net enclosure volume in cubic metres ( $m^3$ ) 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  $1.42 m^3$  is subtracted.
- $V_{out}$  = 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

6.1. 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 shall 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 shall 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 shall be latched to a fixed volume when the enclosure is held at an ambient temperature of 293 K. This nominal volume shall be repeatable within  $\pm 0.5$  per cent of the reported value.
    - 2.1.2. The net internal volume is determined by subtracting 1.42 m<sup>3</sup> 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 m<sup>3</sup>.
    - 2.1.3. The chamber shall be checked as in paragraph 2.3. If the hydrogen mass does not agree with the injected mass to within  $\pm 2$  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 shall 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 shall be maintained at 293 K  $\pm$  2 K, throughout the four-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) shall be calibrated, then zeroed and spanned.
    - 2.2.4. The enclosure shall 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  $C_{H2i}$ ,  $T_i$  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  $C_{H2f}$ ,  $T_f$  and  $P_f$ .
- 2.2.8. The change in mass of hydrogen in the enclosure shall be calculated over the time of the test in accordance with paragraph 2.4. and shall 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 shall 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 shall 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 shall 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  $C_{H2i}$ ,  $T_i$  and  $P_i$  used in the enclosure calibration.
- 2.3.5. The enclosure shall 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 shall be measured to an accuracy of  $\pm 2$  per cent of the measured value.
- 2.3.7. The contents of the chamber shall 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 shall be within  $\pm 2$  per cent of the mass of hydrogen measured in paragraph 2.3.6.
- 2.3.9. The contents of the chamber shall 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.

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

where:

$M_{H_2}$  = hydrogen mass, in grams

$C_{H_2}$  = measured hydrogen concentration 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 analyser

The analyser 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 three, then the number of calibration points shall be at least the number of the polynomial degree plus two.
- 3.3. The calibration curve shall not differ by more than two 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 analyser 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 analyser range calibrated.
- This table shall also contain other relevant data such as:
- (a) Date of calibration;
  - (b) Span and zero potentiometer readings (where applicable);
  - (c) Nominal scale;
  - (d) Reference data of each calibration gas used;
  - (e) Real and indicated value of each calibration gas used together with the percentage differences;
  - (f) 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 shall be common to vehicles within the family. In some cases there may be interaction of parameters. These effects shall 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:

  - (a) Trade name or mark of the battery;
  - (b) Indication of all types of electro-chemical couples used;
  - (c) Number of battery cells;
  - (d) Number of battery modules;
  - (e) Nominal voltage of the battery (V);
  - (f) Battery energy (kWh);
  - (g) Gas combination rate (in per cent);
  - (h) Type(s) of ventilation for battery module(s) or pack;
  - (i) Type of cooling system (if any).

On-board charger:

  - (a) Make and type of different charger parts;
  - (b) Output nominal power (kW);
  - (c) Maximum voltage of charge (V);
  - (d) Maximum intensity of charge (A);
  - (e) Make and type of control unit (if any);
  - (f) Diagram of operating, controls and safety;
  - (g) Characteristics of charge periods.