Official Journal
of the European Union

EN
L series

2026/1695

17.8.2026

Only the original UN/ECE texts have legal effect under international public law. The status and date of entry into force of this Regulation should be checked in the latest version of the UN/ECE status document TRANS/WP.29/343, available at: https://unece.org/status-1958-agreement-and-annexed-regulations

UN Regulation No 100 – Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train [2026/1695]

Incorporating all valid text up to:

05 series of amendments – Date of entry into force: 26 September 2025

This document is meant purely as documentation tool. The authentic and legally binding texts are:

ECE/TRANS/WP.29/2020/109

ECE/TRANS/WP.29/2023/133

ECE/TRANS/WP.29/2021/118

ECE/TRANS/WP.29/2022/64

ECE/TRANS/WP.29/2023/119

ECE/TRANS/WP.29/2024/41

ECE/TRANS/WP.29/2024/122

ECE/TRANS/WP.29/2024/121

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1. Scope

1.1. Part I: Safety requirements with respect to the electric power train of road vehicles of categories M, N and O ([1]), with a maximum design speed exceeding 25 km/h, equipped with electric power train, excluding vehicles permanently connected to the grid.

However, for vehicles of category O, with batteries which are charged by (one of) the vehicle's e-axle(s), the requirements in part I of this UN Regulation shall apply, including those for the REESS (i.e. such batteries are considered as REESS even though they may not provide propulsion).

Part I of this regulation does not cover:

(a) Post-crash safety requirements of road vehicles.

(b) High voltage components and systems which are not galvanically connected to the high voltage bus of the electric power train.

(c) High voltage electricity connection between the towing vehicle and the trailer(s).

1.2. Part II: Safety requirements with respect to the Rechargeable Electrical Energy Storage System (REESS), of road vehicles of categories M, N and O equipped with electric power train, excluding vehicles permanently connected to the grid.

Part II of this Regulation does not apply to a battery whose primary use is to supply power for starting the engine and/or lighting and/or other vehicle auxiliaries' systems.

However, for vehicles of category O, with batteries which are charged by (one of) the vehicle's e-axle(s), the requirements in part II of this UN Regulation shall apply, including those for the REESS (i.e. such batteries are considered as REESS even though they may not provide propulsion.

1.3. Part III: Requirements with respect to the installation of an approved Rechargeable Electrical Energy Storage System (REESS) to the road vehicles of categories M, N and O equipped with electric power train, excluding vehicles permanently connected to the grid.

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 or in case of a vehicle of category O, the vehicle mode when coupled with a towing vehicle in active driving possible mode.

2.2. "*Aqueous electrolyte*" means an electrolyte based on water solvent for the compounds (e.g. acids, bases) providing conducting ions after its dissociation.

2.3. "*Automatic disconnect*" means a device that when triggered, conductively separates the electric energy sources from the rest of the high voltage circuit of the electric power train.

([1]) As defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3.), document ECE/TRANS/WP.29/78/Rev.7, para. 2https://unece.org/transport/vehicle-regulations/wp29/resolutions.

2.4. "*Breakout harness*" means connector wires that are connected for testing purposes to the REESS on the traction side of the automatic disconnect

2.5. "*Cell*" means a single encased electrochemical unit containing one positive and one negative terminals, which exhibits a voltage differential across its two terminals and used as rechargeable electrical energy storage device.

2.6 "*Conductive connection*" means the connection using connectors to an external power supply when the Rechargeable Electrical Energy Storage System (REESS) is charged.

2.7. "*Connector*" means the device that provides mechanical connection and disconnection of high voltage electrical conductors to a suitable mating component including its housing

2.8. "*Coupling system for charging the Rechargeable Electrical Energy Storage System (REESS)*" means the electrical circuit used for charging the REESS from an external electric power supply including the vehicle inlet.

2.9. "*C Rate*" *of* "*n C*" is defined as the constant current of the Tested-Device, which takes 1/n hours to charge or discharge the Tested-Device between 0 per cent of the state of charge and 100 per cent of the state of charge.

2.10. "*Direct contact*" means the contact of persons with high voltage live parts.

2.11. "*Electric energy conversion system*" means a system (e.g. fuel cell) that generates and provides electric energy for electric propulsion.

2.12. "*Electric power train*" means the electrical circuit which includes the traction motor(s), and may include the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the REESS.

2.13. "*Electrical chassis*" means a set made of conductive parts electrically linked together, whose potential is taken as reference.

2.14. "*Electrical circuit*" means an assembly of connected live parts which is designed to be electrically energized in normal operation.

2.15. "*Electrical protection barrier*" means the part that provides protection against direct contact with the high voltage live parts.

2.16. "*Electrolyte leakage*" means the escape of electrolyte from the REESS in the form of liquid

2.17. "*Electronic converter*" means a device capable of controlling and/or converting electric power for electric propulsion.

2.18. "*Enclosure*" means the part enclosing the internal units and providing protection against any direct contact.

2.19. "*Explosion*" means the sudden release of energy sufficient to cause pressure waves and/or projectiles that may cause structural and/or physical damage to the surrounding of the Tested-Device.

2.20. "*Exposed conductive part*" means the conductive part which can be touched under the provisions of the protection degree IPXXB, and which is not normally energized, but which can become electrically energized under isolation failure conditions. This includes parts under a cover that can be removed without using tools.

2.21. "*External electric power supply*" means an alternating current (AC) or direct current (DC) electric power supply outside of the vehicle.

2.22. "*Fire*" means the emission of flames from a Tested-Device. Sparks and arcing shall not be considered as flames.

2.23. "*Flammable electrolyte*" means an electrolyte that contains substances classified as Class 3 "flammable liquid" under "UN Recommendations on the Transport of Dangerous Goods – Model Regulations (Revision 17 from June 2011), Volume I, Chapter 2.3" ([2])

2.24. "*High Voltage*" means the classification of an electric component or circuit, if its working voltage is > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC root mean square (rms).

2.25. "*High voltage bus*" means the electrical circuit, including the coupling system for charging the REESS that operates on high voltage. In case of electrical circuits, that are galvanically connected to each other and fulfilling the voltage condition specified in paragraph 2.42., only the components or parts of the electric circuit that operate on high voltage are classified as a high voltage bus.

2.26. "*Indirect contact*" means the contact of persons with exposed conductive parts.

2.27. "*Live parts*" means the conductive part(s) intended to be electrically energized under normal operating conditions.

2.28. "*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 occupants from direct contact with high voltage live parts, being separated from the passenger compartment by the front bulkhead or the rear bulk head.

2.29. "*Manufacturer*" means the person or body who is responsible to the approval authority for all aspects of the approval process and for ensuring conformity of production. It is not essential that the person or body is directly involved in all stages of the construction of the vehicle or component which is the subject of the approval process

2.30. "*Non-aqueous electrolyte*" means an electrolyte not based on water as the solvent.

2.31. "*Normal operating conditions*" includes operating modes and conditions that can reasonably be encountered during typical operation of the vehicle including driving at legally posted speeds, parking and standing in traffic, as well as, charging using chargers that are compatible with the specific charging ports installed on the vehicle. It does not include conditions where the vehicle is damaged, either by a crash, road debris or vandalization, subjected to fire or water submersion, or in a state where service and or maintenance is needed or being performed.

2.32. "*On-board isolation resistance monitoring system*" means the device which monitors the isolation resistance between the high voltage buses and the electrical chassis.

2.33. "*Open type traction battery*" means a liquid type battery requiring refilling with water and generating hydrogen gas released to the atmosphere.

2.34. "*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 occupants from direct contact with live parts.

([2]) www.unece.org/trans/danger/publi/unrec/rev17/17files_e.html.

2.35. "*Protection degree IPXXB*" means protection from contact with high voltage live parts provided by either an electrical protection barrier or an enclosure and tested using a Jointed Test Finger (IPXXB) as described in Annex 3.

2.36. "*Protection degree IPXXD*" means protection from contact with high voltage live parts provided by either an electrical protection barrier or an enclosure and tested using a Test Wire (IPXXD) as described in Annex 3.

2.37. "*Rechargeable Electrical Energy Storage System (REESS)*" means the rechargeable energy storage system that provides electric energy for electrical propulsion.

A battery whose primary use is to supply power for starting the engine and/or lighting and/or other vehicle auxiliaries' systems is not considered as a REESS.

The REESS may include the necessary systems for physical support, thermal management, electronic controls and casing

2.38. "*REESS subsystem*" means any assembly of REESS components which stores energy. A REESS subsystem may or may not include the entire management system of the REESS.

2.39. "*Rupture*" means opening(s) through the casing of any functional cell assembly created or enlarged by an event, large enough for a 12 mm diameter test finger (IPXXB) to penetrate and make contact with live parts (see Annex 3).

2.40. "*Service disconnect*" means the device for deactivation of the electrical circuit when conducting checks and services of the REESS, fuel cell stack, etc.

2.41. "*Solid insulator*" means the insulating coating of wiring harnesses provided in order to cover and prevent the high voltage live parts from any direct contact

2.42. "*Specific voltage condition*" means the condition that the maximum voltage of a galvanically connected electrical circuit between a DC live part and any other live part (DC or AC) is ≤ 30 V AC (rms) and ≤ 60 V DC.

Note 1: When a DC live part of such an electrical circuit is connected to chassis and the specific voltage condition applies, the maximum voltage between any live part and the electrical chassis is ≤ 30 V AC (rms) and ≤ 60 V DC

Note 2: For pulsating DC voltages (alternating voltages without change of polarity) the DC threshold shall be applied.

2.43. "*State of Charge (SOC)*" means the available electrical charge in a Tested-Device expressed as a percentage of its rated capacity.

2.44. "*Tested-Device*" means either complete REESS or REESS subsystem that is subjected to the tests prescribed by this Regulation.

2.45. "*Thermal event*" means the condition when the temperature within the REESS is significantly higher (as defined by the manufacturer) than the maximum operating temperature.

2.46. "*Thermal runaway*" means an uncontrolled increase of cell temperature caused by exothermic reactions inside the cell.

2.47. "*Thermal propagation*" means the sequential occurrence of thermal runaway within a REESS triggered by thermal runaway of a cell in that REESS.

2.48. "*Type of REESS*" means systems which do not differ significantly in such essential aspects as:

(a) The manufacturer's trade name or mark;

(b) The chemistry, capacity and physical dimensions of its cells;

(c) The number of cells, the mode of connection of the cells and the physical support of the cells;

(d) The construction, materials and physical dimensions of the casing and

(e) The necessary ancillary devices for physical support, thermal management and electronic control.

2.49. "*Vehicle connector*" means the device which is inserted into the vehicle inlet to supply electric energy to the vehicle from an external electric power supply.

2.50. "*Vehicle inlet*" means the device on the externally chargeable vehicle into which the vehicle connector is inserted for the purpose of transferring electric energy from an external electric power supply.

2.51. "*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.

2.52. "*Venting*" means the release of excessive internal pressure from cell or REESS subsystem or REESS in a manner intended by design to preclude rupture or explosion"

2.53. "*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.

2.54. "*Trailer load compartment*" means the compartment of the trailer described by the bodywork. The trailer load compartment is contained by the floor of the loading area and the inner surface of the bodywork as well as inside the storage equipment (e.g. pallet box etc.), if any.

2.55. *"e-axle"* means an axle mounted to a vehicle of category O, generating electrical energy and/or providing electrical propulsion.

Batteries which are charged by (one of) the vehicle's e-axle(s) may include the necessary systems for physical support, thermal management, electronic control and casing.

2.56. "*Common space*" means an area on which two or more information functions (e.g. symbol) may be displayed but not simultaneously.

2.57. "*Alkali metal anodes*" means negative electrodes of the battery cells which are based on lithium, sodium, or potassium, e.g. alkali metal foils (stand alone or supported on a current collector) and alkali metals encapsulated in host structure(s).

3. Application for approval

3.1. Part I: Approval of a vehicle type with regard to specific requirements for the electric power train.

3.1.1. The application for approval of a vehicle type with regard to specific requirements for the electric power train shall be submitted by the vehicle manufacturer or by his duly accredited representative.

3.1.2. It shall be accompanied by the under-mentioned documents in triplicate and following particulars:

3.1.2.1. Detailed description of the vehicle type with regard~~s~~ to the electric power train and the high voltage bus galvanically connected to it.

3.1.2.2. For vehicles with REESS, additional evidence showing that the REESS is in compliance with the requirements of paragraph 6. of this Regulation.

3.1.3. A vehicle representative of the vehicle type to be approved shall be submitted to the Technical Service responsible for conducting the approval tests and, if applicable, at the manufacturer's discretion with the agreement of the Technical Service, either additional vehicle(s), or those parts of the vehicle regarded by the Technical Service as essential for the test(s) referred to in the paragraph 6. of this Regulation.

3.2. Part II: Approval of a Rechargeable Electrical Energy Storage System (REESS)

3.2.1. The application for approval of a type of REESS with regard to the safety requirements of the REESS shall be submitted by the REESS manufacturer or by his duly accredited representative.

3.2.2. It shall be accompanied by the under-mentioned documents in triplicate and comply with the following particulars:

3.2.2.1. Detailed description of the type of REESS as regards the safety of the REESS.

3.2.3. A component(s) representative of the type of REESS to be approved plus, at the manufacturer's discretion, and with the agreement of the Technical Service, those parts of the vehicle regarded by the Technical Service as essential for the test, shall be submitted to the Technical Service responsible for conducting the approval tests.

3.3. The Type Approval Authority shall verify the existence of satisfactory arrangements for ensuring effective control of the conformity of production before type approval is granted.

3.4. In cases where information is shown to be covered by intellectual property rights or to constitute specific know-how of the manufacturer or of their suppliers, the manufacturer or their suppliers shall make available sufficient information to enable the correct verifications referred to in this Regulation. Such information shall be treated on a confidential basis.

3.5. Documentation shall be made available in two parts:

(a) The formal documentation package for the approval, containing the material specified in Annex 1, Appendix 1 or Appendix 2 which shall be supplied to the Approval Authority or its Technical Service at the time of submission of the type approval application. This documentation package shall be used by the Approval Authority or its Technical Service as the basic reference for the approval process. The Approval Authority or its Technical Service shall ensure that this documentation package remains available for at least 10 years from the time when production of the vehicle/REESS type is definitively discontinued.

(b) Additional material relevant to the requirements of this Regulation may be retained by the manufacturer, and available for inspection at the time of type approval. The manufacturer shall ensure that any material available for inspection at the time of type approval remains available for at least a period of 10 years from the time when production of the vehicle and/or REESS type is definitively discontinued.

4. Approval

4.1. An approval number shall be assigned to each approved type in accordance with Schedule 4 of the Agreement (E/ECE/TRANS/505/Rev.3).

4.2. Notice of approval or of refusal or of extension or withdrawal of approval or production definitively 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, Part 1 (for approval of type of vehicle according to Part I or Part III of this Regulation) or Part 2 (for approval of type of REESS according to Part II of this Regulation) as appropriate to this Regulation.

4.3. There shall be affixed, conspicuously and in a readily accessible place specified on the approval form, to every vehicle or REESS conforming to a type approved under this Regulation an international approval mark consisting of:

4.3.1. A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval ([3]).

4.3.2. 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 4.3.1.

4.3.3. In the case of an approval of a REESS the "R" shall be followed by the symbol "ES".

4.4. If the vehicle or REESS conforms to a 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 4.3.1. 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 4.3.1.

4.5. The approval mark shall be clearly legible and shall be indelible.

4.5.1. In the case of a vehicle, the approval mark shall be placed on or close to the vehicle data plate affixed by the manufacturer.

4.5.2. In the case of a REESS, the approval mark shall be affixed on the major element of the REESS by the manufacturer.

4.6. Annex 2 to this Regulation gives examples of the arrangements of the approval mark.

5. Part I: Requirements of a vehicle with regard to specific requirements for the electric power train

5.1. Protection against electrical shock

These electrical safety requirements apply to high voltage buses of electric power train and electrical components which are galvanically connected to the high voltage bus of electric power train under conditions where they are not connected to external high voltage power supplies.

([3]) The distinguishing numbers of the Contracting Parties to the 1958 Agreement are reproduced in Annex 3 to Consolidated Resolution on the Construction of Vehicles (R.E.3), document ECE/TRANS/WP.29/78/Rev.7/Amend.3.

5.1.1. Protection against direct contact

Live parts shall comply with paragraphs 5.1.1.1. and 5.1.1.2. for protection against direct contact. Electrical protection barriers, enclosures, solid insulators and connectors shall not be able to be opened, separated, disassembled or removed without the use of tools or, for vehicles of categories N_2, N_3, M_2, M_3, O_3 and O_4, an operator controlled activation/deactivation device or equivalent.

However, connectors (including the vehicle inlet) are allowed to be separated without the use of tools, if they meet one or more of the following requirements:

(a) They comply with paragraphs 5.1.1.1. and 5.1.1.2. when separated, or

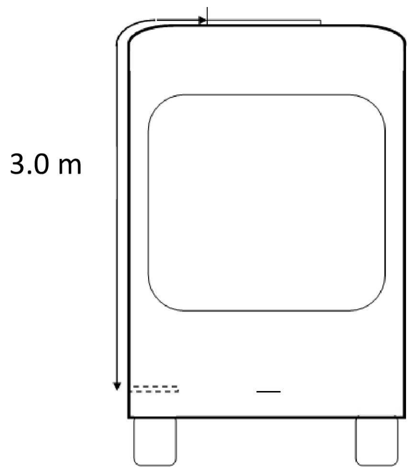
(b) They are provided with a locking mechanism (at least two distinct actions are needed to separate the connector from its mating component). Additionally, other components, not being part of the connector, shall be removable only with the use of tools or, for vehicles of categories N_2, N_3, M_2, M_3, O_3 and O_4, an operator controlled activation/deactivation device or equivalent in order to be able to separate the connector, or

(c) The voltage of the live parts becomes equal or below 60 V DC or equal or below 30 V AC (rms) within 1 s after the connector is separated.

For vehicles of categories N_2, N_3, M_2, M_3, O_3 and O_4, conductive connection devices not energized except during charging of the REESS are exempted from this requirement if located on the roof of the vehicle out of reach for a person standing outside of the vehicle and, for vehicles of category M_2 and M_3, the minimum wrap around distance from the instep of the vehicle to the roof mounted charging devices is 3 m. In case of multiple steps due to an elevated floor inside the vehicle, the wrap around distance is measured from the bottom most step at entry, as illustrated in Figure 1.

Figure 1

Schematic to Measure Wrap-Around Distance



5.1.1.1. For high voltage live parts inside the passenger compartment, or luggage compartment, or trailer load compartment, the protection degree IPXXD shall be provided .

5.1.1.2. For high voltage live parts in areas other than the passenger compartment, or luggage compartment or trailer load compartment, the protection degree IPXXB shall be provided .

5.1.1.3. Service disconnect

For a high voltage service disconnect which can be opened, disassembled or removed without tools, or for vehicles of categories N_2, N_3, M_2, M_3, O_3 and O_4, an operator controlled activation/deactivation device or equivalent, protection degree IPXXB shall be satisfied when it is opened, disassembled or removed.

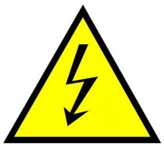
5.1.1.4. Marking

5.1.1.4.1. The symbol shown in Figure 2 shall be present on or near the REESS having high voltage capability. The symbol background shall be yellow, the bordering and the arrow shall be black.

This requirement shall also apply to a REESS which is part of a galvanically connected electrical circuit where the specific voltage condition is not fulfilled, independent of the maximum voltage of the REESS.

Figure 2

Marking of High Voltage Equipment



5.1.1.4.2. The symbol shall also be visible on enclosures and electrical protection 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 electrical protection barriers or enclosures cannot be physically accessed, opened, or removed; unless other vehicle components are removed with the use of tools;

(b) Where electrical protection barriers or enclosures are located underneath the vehicle floor.

(c) Electrical protection barriers or enclosures of conductive connection device for vehicles of categories N_2, N_3, M_2, M_3, O_3 and O_4 which satisfies the conditions prescribed in paragraph 5.1.1.

5.1.1.4.3. 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 electrical protection 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 Ω when there is current flow of at least 0.2 amperes.

The resistance between any two simultaneously reachable exposed conductive parts of the electrical protection barriers that are less than 2.5 m from each other shall not exceed 0.2 Ω. This resistance may be calculated using the separately measured resistances of the relevant parts of electric path.

This requirement is satisfied if the galvanic connection has been established by welding. In case of doubt or if the connection is established by other means than welding, a measurement shall be made by using one of the test procedures described in Annex 4.

5.1.2.3. In the case of vehicles which are intended to be connected to the grounded external electric power supply through the conductive connection between vehicle inlet and vehicle connector, a device to enable the galvanical connection of the electrical chassis to the earth ground for the external electric power supply 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 vehicle manufacturer, by visual inspection or drawings.

The above requirements are only applicable for vehicles when charging from a stationary charging point, with a charging cable of finite length, through a vehicle coupler comprising a vehicle connector and a vehicle inlet.

5.1.3. Isolation resistance

This paragraph shall not apply to electrical circuits that are galvanically connected to each other, where the DC part of these circuits is connected to the electrical chassis and the specific voltage condition is fulfilled.

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 Ω/volt of the working voltage for DC buses, and a minimum value of 500 Ω/volt of the working voltage for AC buses.

The measurement shall be conducted according to Annex 5A "Isolation resistance measurement method for vehicle-based tests".

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 Ω/volt of the working voltage.

However, if all AC high voltage buses are protected by one of the two following measures, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100 Ω/V of the working voltage:

(a) At least two or more layers of solid insulators, electrical protection 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 5A "Isolation resistance measurement method for vehicle based tests".

5.1.3.3. Fuel cell vehicles

In fuel cell vehicles, DC high voltage buses shall have an on-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value of 100 Ω/V. The function of the on-board isolation resistance monitoring system shall be confirmed as described in Annex 6.

The isolation resistance between the high voltage bus of the coupling system for charging the REESS, which is not energized in conditions other than that during the charging of the REESS, and the electrical chassis need not to be monitored.

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

For the vehicle conductive connection device intended to be conductively connected to the grounded external AC power supply and the electrical circuit that is galvanically connected to the vehicle conductive connection device during charging of the REESS, the isolation resistance between the high voltage bus and the electrical chassis shall comply with the requirements of paragraph 5.1.3.1. when the conductive connection is disconnected and the isolation resistance is measured at the high voltage live parts (contacts) of the vehicle conductive connection device. During the measurement, the REESS may be disconnected.

5.1.4. Protection against water effects.

The vehicles shall maintain isolation resistance after exposure to water (e.g. washing, driving through standing water). This paragraph shall not apply to electrical circuits that are galvanically connected to each other, where the DC part of these circuits is connected to the electrical chassis and the specific voltage condition is fulfilled.

5.1.4.1. The vehicle manufacturer can choose to comply with requirements specified in paragraph 5.1.4.2., those specified in paragraph 5.1.4.3., or those specified in paragraph 5.1.4.4.

5.1.4.2. The vehicle manufacturers shall provide evidence and/or documentation to the type-approval authority or technical services as applicable on how the electrical design or the components of the vehicle located outside the passenger compartment or externally attached, after water exposure remain safe and comply with the requirements described in Annex 7A. If the evidence and/or documentation provided is not satisfactory the type-approval authority or technical services or testing entity as applicable shall require the manufacturer to perform a physical component test based on the same specifications as those described in Annex 7A.

5.1.4.3. If the test procedures specified in Annex 7B are performed, just after each exposure, and with the vehicle still wet, the vehicle shall then comply with isolation resistance test given in Annex 5A, and the isolation resistance requirements given in paragraph 5.1.3. shall be met. In addition, after a 24 hour pause, the isolation resistance test specified in Annex 5A shall again be performed, and the isolation resistance requirements given in paragraph 5.1.3. shall be met.

5.1.4.4. If an isolation resistance monitoring system is provided, and the isolation resistance less than the requirements given in paragraph 5.1.3. is detected, a warning shall be indicated to the driver. The function of the on-board isolation resistance monitoring system shall be confirmed as described in Annex 6.

5.2. Rechargeable Electrical Energy Storage System (REESS)

5.2.1. The REESS including related vehicle components, systems and structure as applicable, shall comply with the respective requirements of paragraph 6. of this Regulation.

5.2.2. Requirements for the installation of a REESS

5.2.2.1. The type of REESS shall be fully compatible with the design of the type(s) of vehicle(s).

5.2.2.2. Smoke caused by thermal propagation shall not be released into the passenger compartment. This requirement shall be verified by the design review of the intended venting strategy of the REESS and its installation.

5.2.2.3. Accumulation of gas

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

5.2.3. Warning in the event of failure in REESS

The vehicle shall provide a warning to the driver when the vehicle is in active driving possible mode in the event specified in paragraphs 6.13. to 6.15.

In case of optical warning, the tell-tale shall, when illuminated, be sufficiently bright to be visible to the driver under both daylight and night-time driving conditions, when the driver has adapted to the ambient roadway light conditions.

This tell-tale shall be activated as a check of lamp function either when the propulsion system is turned to the "On" position, or when the propulsion system is in a position between "On" and "Start" that is designated by the manufacturer as a check position. This requirement does not apply to the tell-tale or text shown in a common space.

Notwithstanding the provisions above in case of vehicles of category O, the trailer shall provide an optical and/or audible warning to the driver of the towing vehicle in the event specified in paragraphs 6.13. to 6.15.

In case of vehicles of category O_3 and O_4, the trailer may provide to the towing vehicle a signal to address an optical warning according to this paragraph and/or an audible warning (e.g. transmission via CAN-Bus according to ISO 11992-2) in the event specified in paragraphs 6.13. to 6.15.

5.2.4. Warning in the event of low energy content of REESS.

For pure electric vehicles (vehicles equipped with a powertrain containing exclusively electric machines as propulsion energy converters and exclusively rechargeable electric energy storage systems as propulsion energy storage systems), a warning to the driver in the event of low REESS state of charge shall be provided. Based on engineering judgment, the manufacturer shall determine the necessary level of REESS energy remaining, when the driver warning is first provided.

In case of optical warning, the tell-tale shall, when illuminated, be sufficiently bright to be visible to the driver under both daylight and night-time driving conditions, when the driver has adapted to the ambient roadway light conditions.

This warning signal is not required for vehicles of category O.

5.3. Preventing accidental or unintended vehicle movement

5.3.1. At least a momentary indication shall be given to the driver each time when the vehicle is first placed in "active driving possible mode" after manual activation of the propulsion system.

However, this provision is optional under conditions where an internal combustion engine provides directly or indirectly the vehicle´s propulsion power upon start up and for vehicles of category O.

To ensure that the vehicle of category O does not activate its driving mode independently, it shall be ensured that its propulsion system is only activated if the trailer is coupled to a towing vehicle and if a signal or command or action is transmitted to the trailer propulsion system.

5.3.2. 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. Moreover, in case of vehicles of category M_2 and M_3 with a capacity of more than 22 passengers in addition to the driver, this signal shall already be given when the drivers leave their seat.

However, this provision is optional under conditions where an internal combustion engine provides, directly or indirectly, the vehicle´s propulsion power while leaving the vehicle or driver seat and for vehicles of category O.

5.3.3. If the REESS can be externally charged, vehicle movement by its own propulsion system shall be impossible as long as the vehicle connector is physically connected to the vehicle inlet.

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

In case of vehicles of category O a trailer parking brake shall be automatically activated as long as the trailer connector is physically connected to the trailer inlet.

The above requirements are only applicable for vehicles when charging from a stationary charging point, with a charging cable of finite length, through a vehicle coupler comprising a vehicle connector and a vehicle inlet.

5.3.4. 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. If the REESS has been approved under Part II of this Regulation and installed in accordance with paragraph 5.2.1.1. this test can be omitted for the approval of the vehicle.

5.4.2. The test shall be conducted following the method described in Annex 8 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 8, hydrogen emissions shall be below 125 g during 5 h, or below 25 x t_2 g during t_2 (in h).

5.4.4. During a charge carried out by a charger presenting a failure (conditions given in Annex 8), hydrogen emissions shall be below 42 g. Furthermore the charger shall limit this possible failure to 30 minutes.

5.4.5. All the operations linked to the REESS charging shall be 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 indicated. An important failure is a failure that can lead to a malfunction of the 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 8, Appendix 2.

5.5. Identification of electric power trained vehicles.

5.5.1. On vehicles of the categories M_2/N_2 and M_3/N_3, equipped with a high voltage electric powertrain, labels shall be installed as specified in Annex 10.

5.5.1.1. The requirement of paragraph 5.5.1. shall be considered to be satisfied in the case that the requirement of paragraph 7.1.7. of UN Regulation No. 134 is satisfied.

5.5.2. For hybrid electric vehicles running on diesel or gasoline, the high voltage powertrain shall be considered its first energy source, independent of the capacity of the REESS.

5.5.3. These labels shall be placed on the front of the vehicle and on the left side as well as on the right side of the vehicle; for the side if available in vicinity of a front door. If there is no front door available, the label has to be placed on the first third of the vehicle length.

In addition, for vehicles of category M_2 and M_3, a label shall be fixed to the rear of the vehicle.

6. Part II: Requirements of a Rechargeable Electrical Energy Storage System (REESS) with regard to its safety

6.1. General

The procedures prescribed in Annex 9 of this Regulation shall be applied.

6.2. Vibration

6.2.1. The test shall be conducted in accordance with Annex 9A to this Regulation.

6.2.2. Acceptance criteria

6.2.2.1. During the test, there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS (s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.2.2.2. For a high voltage REESS, the isolation resistance measured after the test in accordance with Annex 5B to this Regulation shall not be less than 100 Ω/Volt.

6.3. Thermal shock and cycling

6.3.1. This test shall be conducted in accordance with Annex 9B to this Regulation.

6.3.2. Acceptance criteria

6.3.2.1. During the test, there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS (s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.3.2.2. For a high voltage REESS, the isolation resistance measured after the test in accordance with Annex 5B to this Regulation shall not be less than 100 Ω/Volt.

6.4. Mechanical impact

6.4.1. Mechanical Shock

At the manufacturer´s choice the test may be performed as, either

(a) Vehicle based tests in accordance with paragraph 6.4.1.1. of this Regulation, or

(b) Component based tests in accordance with paragraph 6.4.1.2. of this Regulation, or

(c) Any combination of (a) and (b) above, for different direction of vehicle travel.

6.4.1.1. Vehicle based test

Compliance with the requirements of the acceptance criteria of paragraph 6.4.1.3. below may be demonstrated by REESS(s) installed in vehicles that have been subjected to vehicle crash tests in accordance with UN Regulation No. 94, Annex 3 or UN Regulation No. 137 (02 series of amendments or later), Annex 3 for frontal impact, and UN Regulation No. 95, Annex 4 for side impact. The ambient temperature and the SOC shall be in accordance with the said Regulations. This requirement is deemed to be met if the vehicle equipped with electric power train operating on high voltage is approved in accordance with UN Regulation No. 94 (04 series of amendments or later) or UN Regulation No. 137 (01 series of amendments or later) for frontal impact and UN Regulation No. 95 (05 series of amendments or later) for lateral impact.

The approval of a REESS tested under this paragraph shall be limited to the specific vehicle type.

6.4.1.2. Component based test

The test shall be conducted in accordance with Annex 9C to this Regulation.

6.4.1.3. Acceptance criteria

During the test there shall be no evidence of:

(a) Fire;

(b) Explosion;

(c1) Electrolyte leakage if tested according to paragraph 6.4.1.1.:

(i) In case of aqueous electrolyte REESS:

For a period from the impact until 60 minutes after the impact, there shall be no electrolyte leakage from the REESS into the passenger compartment and

no more than 7 per cent by volume of the REESS electrolyte with a maximum of 5.0 l leaked from the REESS to the outside of the passenger compartment. The leaked amount of electrolyte can be measured by the usual techniques of determination of liquid volumes after its collection. For containers containing Stoddard, coloured coolant and electrolyte, the fluids shall be allowed to separate by specific gravity then measured;

(ii) In case of non-aqueous electrolyte REESS:

For a period from the impact until 60 minutes after the impact, there shall be no liquid electrolyte leakage from the REESS into the passenger compartment, luggage compartment and no liquid electrolyte leakage to outside the vehicle. This requirement shall be verified by visual inspection without disassembling any part of the vehicle.

(c2) Electrolyte leakage if tested according to paragraph 6.4.1.2.

After the vehicle based test (paragraph 6.4.1.1.), REESS shall remain attached to the vehicle by at least one component anchorage, bracket, or any structure that transfers loads from REESS to the vehicle structure, and REESS located outside the passenger compartment shall not enter the passenger compartment.

After the component based test (paragraph 6.4.1.2.) the Tested-Device shall be retained by its mounting and its components shall remain inside its boundaries.

For a high voltage REESS the isolation resistance of the Tested-Device shall ensure at least 100 Ω/Volt for the whole REESS measured after the test in accordance with Annex 5A or Annex 5B to this Regulation, or the protection degree IPXXB shall be fulfilled for the Tested-Device.

For a REESS tested in accordance with paragraph 6.4.1.2., the evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.4.2. Mechanical integrity

This test applies only to a REESS intended for installation in vehicles of categories M_1 and N_1.

At the manufacturer's choice, the test may be performed as, either:

(a) Vehicle based tests in accordance with paragraph 6.4.2.1. of this Regulation, or

(b) Component based tests in accordance with paragraph 6.4.2.2. of this Regulation.

6.4.2.1. Vehicle specific test

At the manufacturer's choice, the test may be performed as either:

(a) A vehicle based dynamic tests in accordance with paragraph 6.4.2.1.1. of this Regulation, or

(b) A vehicle specific component test in accordance with paragraph 6.4.2.1.2. of this Regulation, or

(c) Any combination of (a) and (b) above, for different directions of vehicle travel.

When the REESS is mounted in a position which is between a line from the rear edge of the vehicle perpendicular to the centre line of the vehicle and 300 mm forward and parallel to this line, the manufacturer shall demonstrate the mechanical integrity performance of the REESS in the vehicle to the Technical Service.

The approval of a REESS tested under this paragraph shall be limited to specific vehicle type.

6.4.2.1.1. Vehicle based dynamic test

Compliance with the requirements of the acceptance criteria of paragraph 6.4.2.3. below may be demonstrated by REESS(s) installed in vehicles that have been subjected to a vehicle crash test in accordance with the Annex 3 to UN Regulations Nos. 94 or 137 for frontal impact, and Annex 4 to Regulation No. 95 for side impact. The ambient temperature and the SOC shall be in accordance with the said Regulations. This requirement is deemed to be met if the vehicle equipped with the electric power train operating on high voltage is approved in accordance with UN Regulation No. 94 (04 series of amendments or later) or UN Regulation No. 137 (02 series of amendments or later) for frontal impact and UN Regulation No. 95 (05 series of amendments or later) for lateral impact.

6.4.2.1.2. Vehicle specific component test

The test shall be conducted in accordance with Annex 9D of this Regulation.

The crush force specified in paragraph 3.2.1. of Annex 9D may be replaced with the value declared by the vehicle manufacturer using the data obtained from either actual crash tests or its simulation as specified in Annex 3 of UN Regulations Nos. 94 or 137 in the direction of travel and according to Annex 4 to UN Regulation No. 95 in the direction

horizontally perpendicular to the direction of travel. These forces shall be agreed by the Technical Service.

The manufacturers may, in agreement with the Technical Services, use forces derived from the data obtained from alternative crash test procedures, but these forces shall be equal to or greater than the forces that would result from using data in accordance with the Regulations specified above.

The manufacturer may define the relevant parts of the vehicle structure used for the mechanical protection of the REESS components. The test shall be conducted with the REESS mounted to this vehicle structure in a way which is representative of its mounting in the vehicle.

6.4.2.2. Component based test

The test shall be conducted in accordance with Annex 9D to this Regulation.

REESS approved according to this paragraph shall be mounted in a position which is between the two planes; (a) a vertical plane perpendicular to the centre line of the vehicle located 420 mm rearward from the front edge of the vehicle, and (b) a vertical plane perpendicular to the centre line of the vehicle located 300 mm forward from the rear edge of the vehicle.

The mounting restrictions shall be documented in Annex 1 – Appendix 2.

The crush force specified in paragraph 3.2.1. of Annex 9D may be replaced with the value declared by the manufacturer, where the crush force shall be documented in Annex 1, Appendix 2 as a mounting restriction. In this case, the vehicle manufacturer who uses such REESS shall demonstrate, during the process of approval for Part I of this Regulation, that the contact force to the REESS will not exceed the figure declared by the REESS manufacturer. Such force shall be determined by the vehicle manufacturer using the data obtained from either actual crash test or its simulation as specified in Annex 3 to UN Regulations Nos. 94 or 137 in the direction of travel and according to Annex 4 to Regulation No. 95 in the direction horizontally perpendicular to the direction of travel. These forces shall be agreed by the manufacturer together with the Technical Service.

The manufacturers may, in agreement with the Technical Services, use forces derived from the data obtained from alternative crash test procedures, but these forces shall be equal to or greater than the forces that would result from using data in accordance with the regulations specified above.

6.4.2.3. Acceptance criteria

During the test there shall be no evidence of:

(a) Fire;

(b) Explosion;

(c1) Electrolyte leakage if tested according to paragraph 6.4.2.1.1.:

(i) In case of aqueous electrolyte REESS:

For a period from the impact until 60 minutes after the impact there shall be no electrolyte leakage from the REESS into the passenger compartment and no more than 7 per cent by volume of the REESS electrolyte with a maximum of 5.0 l leaked from the REESS to the outside of the passenger compartment. The leaked amount of electrolyte can be measured by the usual techniques of determination of liquid volumes after its collection. For containers containing stoddard, coloured coolant and electrolyte, the fluids shall be allowed to separate by specific gravity then measured.

(ii) In case of non-aqueous electrolyte REESS:

For a period from the impact until 60 minutes after the impact, there shall be no liquid electrolyte leakage from the REESS into the passenger compartment, luggage compartment and no liquid electrolyte leakage to outside the vehicle. This requirement shall be verified by visual inspection without disassembling any part of the vehicle.

(c2) Electrolyte leakage if tested according to paragraph 6.4.2.1.2. or paragraph 6.4.2.2.

For a high voltage REESS, the isolation resistance of the Tested-Device shall ensure at least 100 Ω/Volt for the whole REESS measured in accordance with Annex 5A or Annex 5B of this Regulation or the protection degree IPXXB shall be fulfilled for the Tested-Device.

If tested according to paragraph 6.4.2.2., the evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.5. Fire resistance

This test is required for REESS containing flammable electrolyte.

This test is not required when the REESS as installed in the vehicle, is mounted such that the lowest surface of the casing of the REESS is more than 1.5m above the ground. At the request of the manufacturer, this test may be performed when the lowest surface of the casing of the REESS is higher than 1.5 m above the ground. The test shall be carried out on one test sample.

At the manufacturer´s choice the test may be performed as, either:

(a) A vehicle based test in accordance with paragraph 6.5.1. of this Regulation, or

(b) A component based test in accordance with paragraph 6.5.2. of this Regulation.

6.5.1. Vehicle based test

The test shall be conducted in accordance with Annex 9E paragraph 3.2.1. of this Regulation.

The approval of a REESS tested according to this paragraph shall be limited to approvals for a specific vehicle type.

6.5.2. Component based test

The test shall be conducted in accordance with Annex 9E paragraph 3.2.2. of this Regulation.

6.5.3. Acceptance criteria

6.5.3.1. During the test, the Tested-Device shall exhibit no evidence of explosion.

6.6. External short circuit protection

6.6.1. The test shall be conducted in accordance with Annex 9F of this Regulation.

6.6.2. Acceptance criteria;

6.6.2.1. During the test there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS(s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.6.2.2. For a high voltage REESS, the isolation resistance measured after the test in accordance with Annex 5 B to this Regulation shall not be less than 100 Ω/Volt.

6.7. Overcharge protection

6.7.1. The test shall be conducted in accordance with Annex 9G to this Regulation.

6.7.2. Acceptance criteria

6.7.2.1. During the test there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS(s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.7.2.2. For a high voltage REESS, the isolation resistance measured after the test in accordance with Annex 5B to this Regulation shall not be less than 100 Ω/Volt.

6.8. Over-discharge protection

6.8.1. The test shall be conducted in accordance with Annex 9H to this Regulation.

6.8.2. Acceptance criteria

6.8.2.1. During the test there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS(s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.8.2.2. For a high voltage REESS the isolation resistance measured after the test in accordance with Annex 5B to this Regulation shall not be less than 100 Ω/Volt.

6.9. Over-temperature protection

6.9.1. The test shall be conducted in accordance with Annex 9I to this Regulation.

6.9.2. Acceptance criteria

6.9.2.1. During the test there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS(s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.9.2.2. For a high voltage REESS, the isolation resistance measured after the test in accordance with Annex 5B to this Regulation shall not be less than 100 Ω/Volt.

6.10. Overcurrent protection

This test is required for REESS intended for use on vehicles of categories M1 and N1 that have the capability of charging by DC external electricity supply.

6.10.1. The test shall be conducted in accordance with Annex 9J to this Regulation.

6.10.2. Acceptance criteria

6.10.2.1. During the test there shall be no evidence of:

(a) Electrolyte leakage;

(b) Rupture (applicable to high voltage REESS(s) only);

(c) Venting (for REESS other than open-type traction battery);

(d) Fire;

(e) Explosion.

The evidence of electrolyte leakage shall be verified by visual inspection without disassembling any part of the Tested-Device. An appropriate technique shall, if necessary, be used in order to confirm if there is any electrolyte leakage from the REESS resulting from the test. The evidence of venting shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.10.2.2. The overcurrent protection control of the REESS shall terminate charging or the temperature measured on the casing of the REESS shall be stabilized, such that the temperature gradient varies by less than 4 °C through 2 hours after the maximum overcurrent charging level is reached.

6.10.2.3. For a high voltage REESS, the isolation resistance measured after the test in accordance with Annex 5B to this Regulation shall not be less than 100 Ω/V.

6.11. Low-temperature protection.

REESS manufacturer must make available, at the request of the Technical Service with its necessity, the following documentations explaining safety performance of the system level or subsystem level of the vehicle to demonstrate that the REESS monitors and appropriately controls REESS operations at low temperatures at the safety boundary limits of the REESS:

(a) A system diagram;

(b) Written explanation on the lower boundary temperature for safe operation of REESS;

(c) Method of detecting REESS temperature;

(d) Action taken when the REESS temperature is at or lower than the lower boundary for safe operation of the REESS.

6.12. Management of gases emitted from REESS

6.12.1. Under vehicle operation including the operation with a failure, the vehicle occupants shall not be exposed to any hazardous environment caused by emissions from REESS.

6.12.2. Open-type traction batteries shall meet the requirements of paragraph 5.4. of this Regulation with regard to hydrogen emissions.

6.12.3. For REESS other than open-type traction battery, the requirement of paragraph 6.12.1. is deemed to be satisfied, if all applicable requirements of the following tests are met: paragraph 6.2. (vibration), paragraph 6.3. (thermal shock and cycling), paragraph 6.6. (external short circuit protection), paragraph 6.7. (overcharge protection), paragraph 6.8. (over-discharge protection), paragraph 6.9. (over-temperature protection), paragraph 6.10. (overcurrent protection) and paragraph 6.15. (thermal propagation).

6.13. Warning in the event of operational failure of vehicle controls that manage REESS safe operation.

The REESS or vehicle system shall provide a signal to activate the warning specified in paragraph 5.2.3. in the event of operational failure of the vehicle controls (e.g. input and output signals to the management system of REESS, sensors within REESS, etc.) that manage the safe operation of the REESS. REESS or vehicle manufacturer shall make available, at the request of the Technical Service with its necessity, the following documentation explaining safety performance of the system level or subsystem level of the vehicle:

6.13.1. A system diagram that identifies all the vehicle controls that manage REESS operations. The diagram must identify what components are used to generate a warning due to operational failure of vehicle controls to conduct one or more basic operations.

6.13.2. A written explanation describing the basic operation of the vehicle controls that manage REESS operation. The explanation must identify the components of the vehicle control system, provide description of their functions and capability to manage the REESS, and provide a logic diagram and description of conditions that would lead to triggering of the warning.

6.14. Warning in the case of a thermal event within the REESS.

The REESS or vehicle system shall provide a signal to activate the warning specified in paragraph 5.2.3. in the case of a thermal event in the REESS (as specified by the manufacturer). REESS or vehicle manufacturer shall make available, at the request of the Technical Service with its necessity, the following documentation explaining safety performance of the system level or subsystem level of the vehicle:

6.14.1. The parameters and associated threshold levels that are used to indicate a thermal event (e.g. temperature, temperature rise rate, SOC level, voltage drop, electrical current, etc.) to trigger the warning.

6.14.2. A system diagram and written explanation describing the sensors and operation of the vehicle controls to manage the REESS in the event of a thermal event.

6.15. Thermal propagation

For a REESS containing flammable electrolyte or alkali metal anodes, the vehicle occupants shall not be exposed to any hazardous environment caused by thermal propagation which is triggered by an internal short circuit leading to a single cell thermal runaway. To ensure this, the requirements of paragraphs 6.15.1. and 6.15.2. shall be satisfied in accordance with the verification procedure described in paragraph 6.15.3.

The requirements of this paragraph do not apply to REESS that are solely installed on vehicles of category O nor to batteries on vehicles of category O used for recuperation only.

6.15.1. The REESS or vehicle system shall provide a signal to activate the warning specified in paragraph 5.2.3. in the event of a thermal propagation which is triggered by an internal short circuit leading to a single cell thermal runaway, so that the occupants have time to exit the vehicle.

This requirement is deemed to be met if one of the below conditions is satisfied:

(a) the presence of a hazardous situation as defined by pass/fail criteria in paragraph 6.15.3.4. does not occur within 5 minutes following the warning signal; or

(b) the single cell thermal runaway does not lead to thermal propagation in the REESS during 2 hours after its triggering; or

(c) the single cell thermal runaway cannot be triggered and this is confirmed by repeating the same test procedure (i.e. the same trigger method and the same test level) or by conducting a cell level test.

In case of the conditions (b) or (c), the warning indication specified in paragraph 6.15.1. is not mandatory.

6.15.1.1. The REESS or vehicle manufacturer shall make available the following documentation:

(a) The parameters (for example, temperature, voltage or electrical current) which trigger the warning indication.

(b) Description of the warning system.

6.15.2. The REESS or vehicle system shall have functions or characteristics in the cell, REESS or vehicle intended to protect vehicle occupants (as described in paragraph 6.15.) in conditions caused by thermal propagation which is triggered by an internal short circuit leading to a single cell thermal runaway.

6.15.3. The verification process of thermal propagation safety compliance

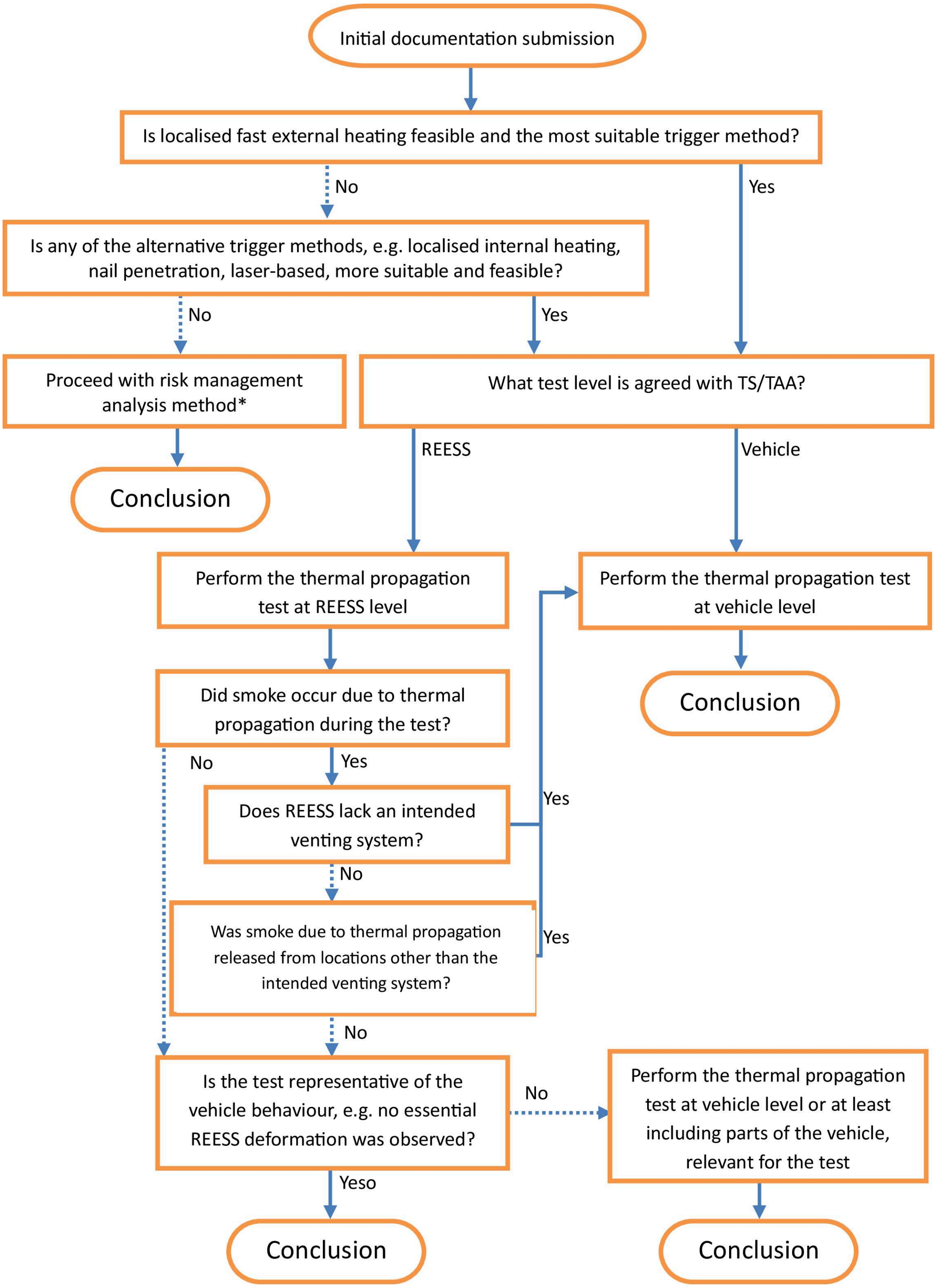
Recognizing that there are different REESS and vehicle designs on the market, and to ensure the technical neutrality of this requirement, the verification of thermal propagation safety compliance follows a multistep approach described in paragraphs 6.15.3.1. to 6.15.3.4.

Conformance with thermal propagation safety is either demonstrated by physical testing (as described in Annex 9K) or when it is deemed that physical testing is not possible without compromising the REESS safety design, e.g. because REESS design precludes disassembly, by a systematic risk management analysis method (paragraph 6.15.4.). The Type Approval Authority and the Technical Service shall determine, with the help of documentation provided by the manufacturer, whether the physical testing is possible without compromising the safety functions or the design of the vehicle and/or REESS.

If the REESS is designed to be charged only by an energy source on the vehicle and its capacity in Ah multiplied by its nominal voltage does not exceed 2 kWh, only the risk management analysis according to paragraph 6.15.4. needs to be performed.

Figure 3

Decision Flow of Verification Process (Informative, not legally binding)



* For REESS designed to be charged only by an energy source on the vehicle and with capacity in Ah multiplied by its nominal voltage not exceeding 2 kWh, only the risk management analysis according to paragraph 6.15.4. needs to be performed.

6.15.3.1. Step 1: Initial documentation submission

The manufacturer shall provide technical documentation containing:

(a) A system diagram of all relevant physical systems and components;

(b) A diagram showing the functional operation of the relevant systems and components, identifying all risk mitigation functions or characteristics;

(c) For each identified risk mitigation function or characteristic implemented, the physical system or component which implements the function shall be identified and the operating strategy described;

(d) the maximum operating temperature;

(e) The recommendations on the feasibility for conducting the physical testing;

(f) If applicable, the recommendations on a more suitable and feasible trigger method including appropriate parameters for the details of the trigger method, the preparation and instrumentation of the Tested-Device; and

(g) If applicable, the recommendation on pre-instrumentation of the triggering and measuring devices including sufficient details of such pre-instrumentation.

Relevant systems and components are those which contribute to protection of vehicle occupants from any hazardous situation caused by thermal propagation triggered by a single cell thermal runaway.

6.15.3.2. Step 2: Selection of trigger method

Technical Service shall start the selection process for the trigger method for physical testing of thermal propagation safety performance by considering the localized fast external heating first. Alternative methods, e.g. localized internal heater, nail penetration or laser-based trigger, may be used if one of those methods is recommended by the manufacturer and recognized as more suitable for the REESS design by the Technical Service to cause the single cell thermal runaway satisfying the criteria given in Annex 9K, paragraph 5. The decision of the Technical Service shall be duly documented and justified in the test report.

Test method descriptions for the respective trigger methods are found in Annex 9K – Appendices 1 to 4.

6.15.3.3. Step 3: Selection of test level

Either the vehicle-based test or the component-based test shall be performed.

If the REESS casing lacks an intended venting system and smoke due to thermal propagation occurs during the test, or if this smoke is released from locations other than the intended venting system, the vehicle-based test shall be carried out. In addition, it shall be demonstrated that the component-based test is representative of a vehicle-level behaviour. In case vehicle parts may affect the outcome of the test, e.g. due to phenomena like essential deformation etc., these shall be included in the test set-up, in agreement with the Technical Service and Type Approval Authority. In case of doubt, the thermal propagation test shall be performed at the vehicle level or shall at least include the parts of the vehicle relevant for the test.

6.15.3.4. Pass and fail criteria for the physical thermal propagation test

For 5 minutes following the signal to activate the warning indication, none of the following hazardous situations caused by thermal propagation shall occur:

(a) Fire;

(b) Explosion;

(c) Smoke release into the passenger compartment.

The warning indication may occur either when the triggered cell enters thermal runaway or when the REESS has reliably identified a thermal propagation event, provided that the safety objectives listed above are met.

For the vehicle-based test, evidence of a hazardous condition, i.e. fire, explosion and smoke release into the passenger compartment, shall be verified by visual inspection without disassembling any part of the Tested-Device or vehicle.

For the component-based test, evidence of a hazardous condition, i.e. fire, explosion and smoke from thermal propagation not escaping the REESS through the intended venting system, shall be verified by visual inspection without disassembling any part of the Tested-Device.

6.15.3.4.1. If no thermal propagation is observed during the 2 hours after the thermal runaway was triggered in the initiation cell, the requirements of paragraph 6.15.3.4. are deemed to be satisfied.

6.15.3.4.2. If thermal runaway is not triggered during the test with the chosen trigger method, and confirmed by repetition of the same test procedure (i.e. the same trigger method and the same test level) or by conducting a cell level test with the same trigger method, the requirements of paragraph 6.15.3.4. are deemed to be satisfied.

6.15.4. Risk management analysis method (if applicable/required following paragraph 6.15.3.)

The manufacturer shall perform and document a risk assessment to consider occupant protection in normal operating conditions as defined in paragraph 2.31. The risk analysis shall be holistic and follow a systematic procedure including hardware and software aspects, (see for example ISO 6469-1:2019/AMD 2022 and ISO 26262 or equivalent standards for additional guidance). The work product shall explain the safety performance of the vehicle systems in conditions caused by thermal propagation which is triggered by an internal short circuit leading to a single cell thermal runaway.

The manufacturer shall make available a high-level report including essential data and a summary of important information on occupant protection in the case of a single cell thermal runaway and thermal propagation from the risk assessment and the risk reduction activities to the Type Approval Authority and Technical Service. The report shall comprise four parts that relate to paragraphs 6.15.4.1., 6.15.4.2., 6.15.4.3. and 6.15.4.4. below.

The Type Approval Authority and/or Technical Service shall assess the risk management analysis with regard to ensuring the safety of the occupants in the event of thermal propagation which is triggered by an internal short circuit leading to a single cell thermal runaway.

6.15.4.1. System analysis

The system analysis shall include:

(a) A system diagram of all relevant physical systems and components;

(b) Description of systems and components relevant to single-cell thermal runaway and thermal propagation due to internal short circuit and their interoperability. Relevant systems and components are those which contribute to protection of vehicle occupants from hazardous effects caused by thermal propagation triggered by a single cell thermal runaway include, but are not limited to REESS, sensors, thermal management system, battery management systems;

(c) A description of warning indication and of operating logic; and

(d) Functional analyses identifying the conditions leading to single cell thermal runaway, i.e. internal short circuit of the cell, and allocating them to the corresponding components or functional units or subsystems;

6.15.4.2. Risk identification and mitigation

A risk identification and mitigation analysis using appropriate industry standard methodology (for guidance, see for example, IEC 61508, MIL-STD 882E, ISO 26262, AIAG & VDA FMEA Handbook, fault analysis as in SAE J2929, or similar) documents: the hazards to vehicle occupants caused by thermal propagation triggered by an internal short circuit leading to a single cell thermal runaway, and the reduction of risk resulting from implementation of the identified risk mitigation functions or characteristics. The severity of the thermal event and the risk of propagation to adjacent cells in the battery pack shall be determined.

The risk identification and mitigation analysis shall include, as appropriate:

(a) Risk mitigation by design;

(b) Risk mitigation by manufacturing control;

(c) Risk mitigation by other means.

The risk analysis shall also include information and justifications about any assumptions on system performance characteristics and properties, model behaviour or relative relevance and the likelihood of specified risk scenarios.

The risk assessment is limited to occupant protection for the relevant operational design domain of REESS and the vehicle.

6.15.4.3. Risk mitigation effectiveness – validation and verification

The effectiveness of each of the risk reduction measures shall be analysed and evaluated. Effectiveness may be analysed by testing, analysis, simulation, models, reference to scientific papers, field data and/or other appropriate methods, either singly or in combination. Effectiveness assessments shall fulfil the requirements of paragraphs 6.15.4.3.1. and 6.15.4.3.2., as appropriate.

6.15.4.3.1. Test and verification methods

Test and verification methods used for unit testing, implementation testing and validation shall be documented, clearly identifying which safety functionalities are addressed with the respective methods. Recognized industry standard tests, for example ISO, IEC, SAE or equivalent, should be used when available and appropriate for the testing purposes. In the absence of appropriate industry standard methods and tests, the manufacturer shall design test methods and verification techniques that are feasible to verify component and/or system performance as required to verify and validate the effectiveness of the risk mitigation strategy. Any such methods used shall be explicitly documented, including an explanation of what property, capability or attribute that is tested and the suitability of the method to generate the data required, as well as the rationale for why the method is appropriate.

6.15.4.3.2. Data sources and quality requirements

The data set shall evaluate performance of the components and functional units that have been identified in the allocation process. The relevance and appropriateness of the data shall be described and justified. Major uncertainty factors shall be identified and quantified as far as possible.

Data may include technical specifications and verifying test reports from suppliers and/or manufacturers, mathematical simulations from theoretical or empirical system models, scientific reports and publications, as well as field data.

All relevant results available shall be gathered to create a full consistent report. The sources of externally derived data shall be identified.

A completeness check shall be conducted so as to ensure that all relevant information and data needed for the interpretation are available and complete.

A sensitivity check shall be conducted to evaluate the reliability of the final results and the conclusions by determining how they are affected by uncertainties in the data, allocation methods or assumptions made about the REESS.

6.15.4.4. Conclusions [4]

(a) The concluding part of the report shall comprise a brief summary of the major results of the risk management analysis and a statement that the requirements in paragraphs 6.15.1. and 6.15.2. are satisfied, including: the methods used are scientifically and technically valid for the scope of the risk management analysis;

(b) The data used are appropriate and reasonable in relation to the intention of the risk management analysis;

(c) The interpretations are relevant and reflect the assumptions made and the limitations identified for the study.

This part may be in the form of an internal or external critical review report, if the manufacturer has such a process in place.

6.16. Communication between vehicle and REESS.

REESS and vehicle shall be compatible with regard to their communication.

7. Part III: Requirements for the installation of an approved Rechargeable Electrical Energy Storage System (REESS) for the purpose of a vehicle approval

7.1. For a REESS which has been type approved in accordance with Part II of this Regulation, installation shall be in accordance with the instructions provided by the manufacturer of the REESS, and in conformity with the description provided in Annex 1, Part 2 to this Regulation.

7.2. The requirements stated in paragraphs 5.1. to 5.1.4.4. and paragraphs 5.2.2. to 5.5.3. above shall be met.

8. Modifications and extension of the type approval

8.1. Every modification of the vehicle or REESS type with regard to this Regulation shall be notified to the Type Approval Authority which approved the vehicle or REESS type. The Authority may then either:

(a) Decide, in consultation with the manufacturer, that a new type approval is to be granted; or

(b) Apply the procedure contained in paragraph 7.1.1. (Revision) and, if applicable, the procedure contained in paragraph 7.1.2. (Extension).

8.1.1. Revision

When details recorded in the information documents of Annex 1 - Appendix 1 or Annex 1 - Appendix 2 have changed and the Type Approval Authority considers that the modifications made are unlikely to have appreciable adverse effect, and that in any case the vehicle still meets the requirements, the modification shall be designated a "revision".

In such a case, the Type Approval Authority shall issue the revised pages of the information documents of Annex 1 – Appendix 1 or Annex 1 – Appendix 2 as necessary, marking each revised page to show clearly the nature of the modification and the date of reissue. A consolidated, updated version of the information documents of Annex 1 – Appendix 1 or Annex 1 – Appendix 2, accompanied by a detailed description of the modification, shall be deemed to meet this requirement.

[4] The manufacturer will be accountable for the verity and integrity of the documentation.

8.1.2. Extension

The modification shall be designated an "extension" if, in addition to the change of the particulars recorded in the information folder:

(a) Further inspections or tests are required; or

(b) Any information on the communication document (with the exception of its attachments) has changed; or

(c) Approval to a later series of amendments is requested after its entry into force.

9. Conformity of production

The conformity of production procedure shall comply with the requirements set out in Schedule 1 of the Agreement (E/ECE/TRANS/505/Rev.3).

9.1. Vehicles or REESS approved under this Regulation shall be so manufactured as to conform to the type approved by meeting the requirements of the relevant part(s) of this Regulation.

9.2. In order to verify that the requirements of paragraph 8.1. are met, appropriate production checks shall be carried out.

10. Penalties for non-conformity of production

10.1. The approval granted in respect of a vehicle/REESS type, pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 8. above are not complied with.

10.2. 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 copy of the approval form bearing at the end, in large letters, the signed and dated annotation "APPROVAL WITHDRAWN".

11. Production definitively discontinued

If the holder of the approval completely ceases to manufacture a vehicle/REESS type approved in accordance with this Regulation, he shall so inform the Type Approval Authority which granted the approval. Upon receiving the relevant communication, that Type Approval Authority shall inform thereof the other Contracting Parties to the Agreement applying this Regulation by means of a copy of the approval form bearing at the end, in large letters, the signed and dated annotation "PRODUCTION DISCONTINUED".

12. Names and addresses of Technical Services responsible for conducting approval tests and of Type Approval Authorities

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 Type Approval Authorities which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval or production definitively discontinued, issued in other countries are to be sent.

13. Transitional provisions

13.1. General

13.1.1. Contracting Parties applying this Regulation may grant type approvals according to any of the preceding series of amendments to this Regulation.

13.1.2. Contracting Parties applying this Regulation shall continue to grant extensions of existing approvals to any of the preceding series of amendments to this Regulation.

13.2. Transitional provisions applicable to the 03 series of amendments

13.2.1. As from the official date of entry into force of the 03 series of amendments, no Contracting Party applying this Regulation shall refuse to grant or refuse to accept type approvals under this Regulation as amended by the 03 series of amendments.

13.2.2. As from 1 September 2023, Contracting Parties applying this Regulation shall not be obliged to accept type approvals to the preceding series of amendments, first issued after 1 September 2023.

13.2.3. Until 1 September 2025, Contracting Parties applying this Regulation shall accept type approvals to the preceding series of amendments, first issued before 1 September 2023.

13.2.4. As from 1 September 2025, Contracting Parties applying this Regulation shall not be obliged to accept type approvals issued to the preceding series of amendments to this Regulation.

13.3. Transitional provisions applicable to the 04 series of amendments.

13.3.1. As from the official date of entry into force of the 04 series of amendments, no Contracting Party applying this UN Regulation shall refuse to grant or refuse to accept UN type approvals under this UN Regulation as amended by the 04 series of amendments.

13.3.2. As from 1 September 2026, Contracting Parties applying this UN Regulation shall not be obliged to accept UN type approvals to any of the preceding series of amendments that were first issued on or after 1 September 2026.

13.3.3. Until 1 September 2027, Contracting Parties applying this UN Regulation shall accept UN type approvals to the 03 series of amendments that were first issued before 1 September 2026.

13.3.4. As from 1 September 2027, Contracting Parties applying this Regulation shall not be obliged to accept type approvals issued to any of the preceding series of amendments to this Regulation.

13.3.5. Notwithstanding paragraph 13.3.4., Contracting Parties applying this Regulation shall continue to accept type approvals issued according to the 03 series of amendments of this Regulation, for the vehicles and vehicle systems which are not affected by the changes introduced by the 04 series of amendments."

13.3.6. Notwithstanding the transitional provisions above, Contracting Parties who start to apply this Regulation after the date of entry into force of the 04 series of amendments are not obliged to accept type approvals which were granted in accordance with any of the preceding series of amendments to this Regulation.

13.4. Transitional provisions applicable to the 05 series of amendments.

13.4.1. As from the official date of entry into force of the 05 series of amendments, no Contracting Party applying this Regulation shall refuse to grant or refuse to accept type approvals under this Regulation as amended by the 05 series of amendments.

13.4.2. As from 1 September 2027, Contracting Parties applying this Regulation shall not be obliged to accept type approvals to any of the preceding series of amendments, first issued after 1 September 2027.

13.4.3. Until 1 September 2029, Contracting Parties applying this Regulation shall accept type approvals to any of the preceding series of amendments, first issued before 1 September 2027, provided the transitional provisions in these respective preceding series of amendments foresee this possibility.

13.4.4. As from 1 September 2029, Contracting Parties applying this Regulation shall not be obliged to accept type approvals issued to any of the preceding series of amendments to this Regulation.

13.4.5. Notwithstanding paragraph 13.4.4. however, until 1 September 2030, Contracting Parties applying this Regulation shall continue to accept type approvals issued according to the 03 (subject to paragraph 13.3.5.) or 04 series of amendments to this Regulation, applying the provisions in paragraph 6.15.1. (a) of the 03 or 04 series of amendments to this Regulation, first issued before 1 September 2027.

13.4.6. Notwithstanding paragraph 13.4.4., Contracting Parties applying this Regulation shall continue to accept type approvals issued according to the 03 (subject to paragraph 13.3.5.) or 04 series of amendments to this Regulation, for the vehicles/vehicle systems which are not affected by the changes introduced by the 05 series of amendments.

13.4.7. Notwithstanding the transitional provisions above, Contracting Parties who start to apply this Regulation after the date of entry into force of the 05 series of amendments are not obliged to accept type approvals which were granted in accordance with any of the preceding series of amendments to this Regulation / are only obliged to accept type approval granted in accordance with the 05 series of amendments.

ANNEX 1

PART 1

Communication

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

E [1] ...

Issued by: Name of administration:
...
...
...
...

Concerning [2]: Approval granted,
Approval extended,
Approval refused,
Approval withdrawn,
Production definitively discontinued,

of a vehicle type with regard to its electrical safety 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. REESS type: ...

6.1.1. The approval number of the REESS or descriptions of the REESS [2]

6.2. Working voltage: ...

6.3. Propulsion system (e.g. hybrid, electric): ...

7. Vehicle submitted for approval on: ...

8. Technical Service responsible for conducting approval tests: ...

...

(1) Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).
(2) Strike out what does not apply.

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) (2): ....

13. Approval granted/extended/refused/withdrawn (2): ....

14. Place: ....

15. Date: ....

16. Signature: ....

17. The documents filed with the request for approval or extension may be obtained on request.

18. Remarks: ....

PART 2

Communication

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

issued by: Name of administration:
....
....
....

Concerning: [2] Approval granted
Approval extended
Approval refused
Approval withdrawn
Production definitively discontinued

of a REESS type as component/separate technical unit [2] pursuant to Regulation No. 100

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

1. Trade name or mark of the REESS: ....

2. Type of REESS: ....

3. Manufacturer's name and address: ....

4. If applicable, name and address of manufacturer's representative: ....

5. Description of the REESS: ....

6. Installation restrictions applicable to the REESS as described in paragraphs 6.4., 6.5., 6.10., 6.15. and 6.16: ....

6.1. Intended category of vehicles for installing the REESS...

7. REESS submitted for approval on: ....

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) [2]: ....

13. Approval granted/extended/refused/withdrawn [2]: ....

14. Place: ....

(1) Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).
(2) Strike out what does not apply.

15. Date: ....

16. Signature: ....

17. The documents filed with the request for approval or extension may be obtained on request.

18. Remarks: ....

Annex 1 – Appendix 1

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: ....

1.8. Approval number of the REESS: ....

2. Electric motor (traction motor)

2.1. Type (winding, excitation): ....

2.2. Maximum net power and / or maximum 30 minutes power (kW): ....

3. REESS

3.1. Trade name and mark of the REESS: ....

3.2. Indication of all types of cells: ....

3.2.1. The cell chemistry: ....

3.2.2. Physical dimensions: ....

3.2.3. Capacity of the cell (Ah): ....

3.3. Description or drawing(s) or picture(s) of the REESS explaining:

3.3.1. Structure: ....

3.3.2. Configuration (number of cells, mode of connection, etc.): ....

3.3.3. Dimensions: ....

3.3.4. Casing (construction, materials and physical dimensions): ....

3.4. Electrical specification: ……………………………………………………………………………

3.4.1. Nominal voltage (V): ……………………………………………………………………………

3.4.2. Working voltage (V): ……………………………………………………………………………

3.4.3. Capacity (Ah): ……………………………………………………………………………

3.4.4. Maximum current (A): ……………………………………………………………………………

3.5. Gas combination rate (in per cent): ……………………………………………………………………………

3.6. Description or drawing(s) or picture(s) of the installation of the REESS in the vehicle: ……………………………

3.6.1. Physical support: ……………………………………………………………………………

3.7. Type of thermal management ……………………………………………………………………………

3.8. Electronic control: ……………………………………………………………………………

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 1 - Appendix 2

Essential characteristics of REESS

1. REESS

1.1. Trade name and mark of the REESS: ……………………………………………………………………

1.1.1. Type of REESS ……………………………………………………………………………………

1.2. Indication of all types of cells: ……………………………………………………………………

1.2.1. The cell chemistry: ………………………………………………………………………………

1.2.2. Physical dimensions: ……………………………………………………………………………

1.2.3. Capacity of the cell (Ah): …………………………………………………………………………

1.3. Description or drawing(s) or picture(s) of the REESS explaining

1.3.1. Structure: …………………………………………………………………………………………

1.3.2. Configuration (number of cells, mode of connection, etc.): ……………………………………………

1.3.3. Dimensions: ………………………………………………………………………………………

1.3.4. Casing (construction, materials and physical dimensions): ……………………………………………

1.4. Electrical specification

1.4.1. Nominal voltage (V):v

1.4.2. Working voltage (V): ……………………………………………………………………………

1.4.3. Capacity (Ah): ……………………………………………………………………………………

1.4.4. Maximum current (A): ……………………………………………………………………………

1.5. Gas combination rate (in percentage): …………………………………………………………………

1.6. Description or drawing(s) or picture(s) of the installation of the REESS in the vehicle: ……………………

1.6.1. Physical support: …………………………………………………………………………………

1.7. Type of thermal management: ………………………………………………………………………

1.8. Electronic control: …………………………………………………………………………………

1.9. Category of vehicles on which the REESS can be installed: ……………………………………………

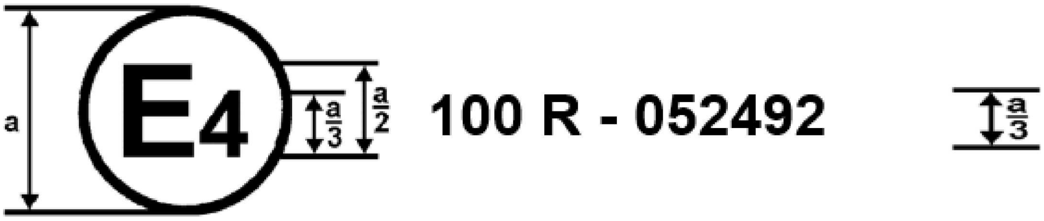
ANNEX 2

Arrangements of the approval marks

MODEL A

(See paragraph 4.4. of this Regulation)

Figure 1



a = 8 mm min

The approval mark in Figure 1 affixed to a vehicle shows that the road vehicle type concerned has been approved in the Netherlands (E 4), pursuant to Regulation No. 100, and under the approval number 052492. 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 05 series of amendments.

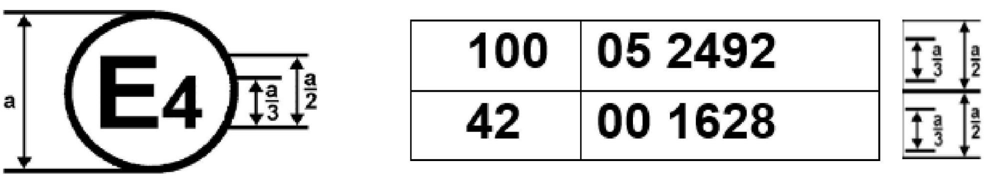
Figure 2

a = 8 mm min.

The approval mark in Figure 2 affixed to a REESS shows that the REESS type ("ES") concerned has been approved in the Netherlands (E 4), pursuant to Regulation No. 100, and under the approval number 052492. 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 05 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 05 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 degrees 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

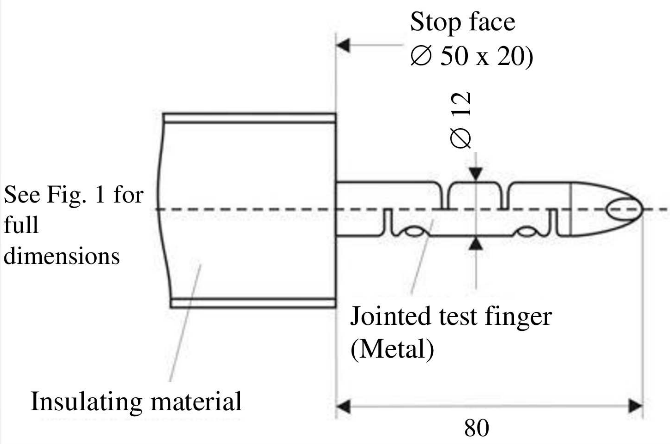
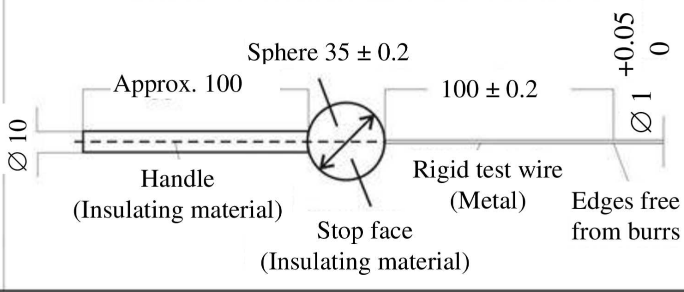
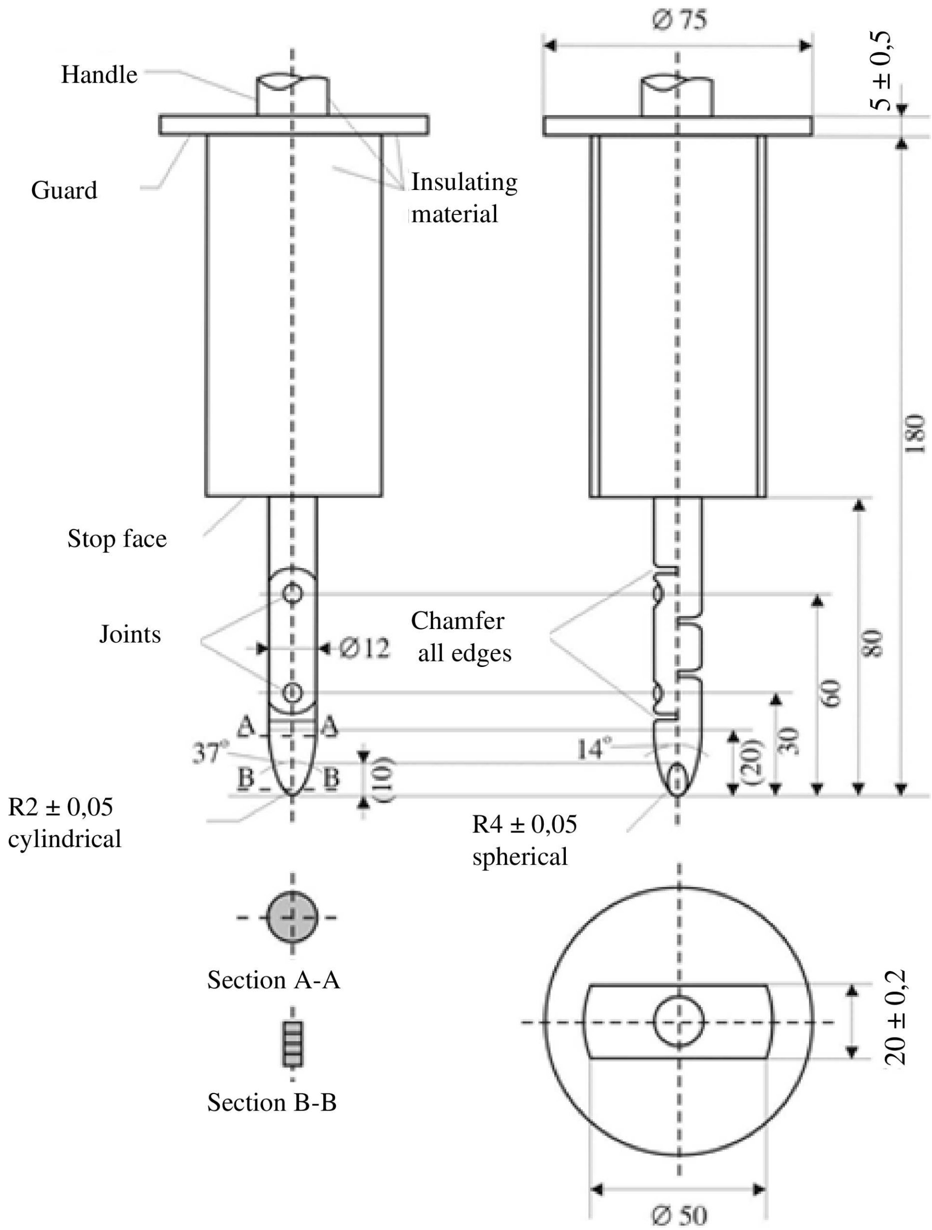
First numeral	Addit. letter	Access probe (Dimensions in mm)	Test force
2	B	**Jointed test finger** 	10 N ± 10%
4, 5, 6	D	**Test wire 1.0 mm diameter, 100 mm long** 	1 N ± 10%

Figure 1

Jointed Test Finger



Material: metal, except where otherwise specified

Linear dimensions in millimeters

Tolerances on dimensions without specific tolerance:

(a) On angles: 0/-10 seconds;

(b) On linear dimensions:

 (i) up to 25 mm: 0/-0.05 mm:

 (ii) over 25 mm: ±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

Verification of potential equalization

1. Test method using a resistance tester.

The resistance tester is connected to the measuring points (typically, electrical chassis and electro conductive enclosure/electrical protection barrier) and the resistance is measured using a resistance tester that meets the specification that follows:

(a) Resistance tester: Measurement current at least 0.2 A;

(b) Resolution: 0.01 Ω or less;

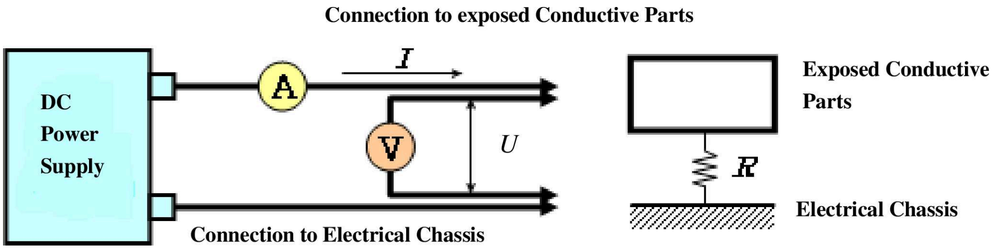
(c) The resistance R shall be less than 0.1 Ω.

2. Test method using DC power supply, voltmeter and ammeter.

Example of the test method using DC power supply, voltmeter and ammeter is shown below.

Figure 1

Example of Test Method using DC Power Supply



2.1. Test Procedure.

The DC power supply, voltmeter and ammeter are connected to the measuring points (Typically, electrical chassis and electro conductive enclosure/electrical protection barrier).

The voltage of the DC power supply is adjusted so that the current flow becomes at least 0.2 A.

The current "I" and the voltage "U" are measured.

The resistance "R" is calculated according to the following formula:

$$R = U / I$$

The resistance R shall be less than 0.1 Ω.

Note: If lead wires are used for voltage and current measurement, each lead wire shall be independently connected to the electrical protection barrier/enclosure/electrical chassis. Terminal can be common for voltage measurement and current measurement.

ANNEX 5A

Isolation resistance measurement method for vehicle based tests

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. of this annex, depending on the electrical charge of the live parts or the isolation resistance, etc.

Megohmmeter or oscilloscope measurements are appropriate alternatives to the procedure described below for measuring isolation resistance. In this case, it may be necessary to deactivate the on-board isolation resistance monitoring system.

The range of the electrical circuit to be measured shall be clarified in advance, using electrical circuit diagrams, etc. If the high voltage buses are conductively isolated from each other, isolation resistance shall be measured for each electrical circuit.

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, necessary modification for conducting the measurement may be carried out by stopping of the operation of the device concerned or removing it. Furthermore, when the device is removed, a set of drawings will be used to prove that the isolation resistance between the live parts and the electrical chassis remains unchanged.

These modifications shall not influence the test results.

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

2.1. Measurement method using DC voltage from external 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 isolation 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 REESS as DC voltage source

2.2.1. Test vehicle conditions

The high voltage-bus shall be energized by the vehicle's own REESS and/or energy conversion system and the voltage level of the REESS 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.

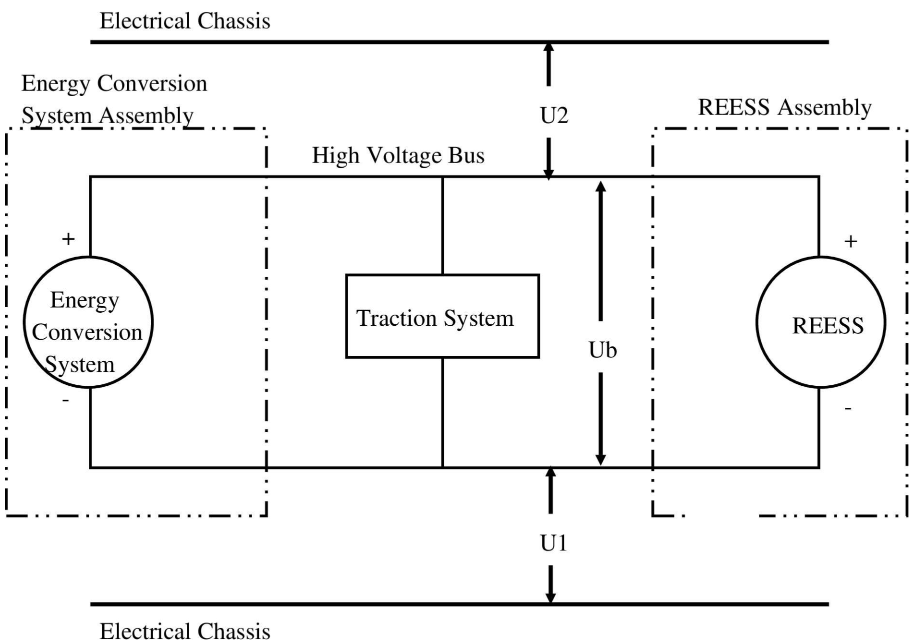
2.2.3. Measurement method

2.2.3.1. First step

The voltage is measured as shown in Figure 1 and the high voltage bus voltage (Ub) is recorded. Ub shall be equal to or greater than the nominal operating voltage of the REESS and/or energy conversion system as specified by the vehicle manufacturer.

Figure 1

Measurement of Ub, U1, U2



2.2.3.2. Second step

Measure and record the voltage (U1) 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 (U2) between the positive side of the high voltage bus and the electrical chassis (see Figure 1).

2.2.3.4. Fourth step

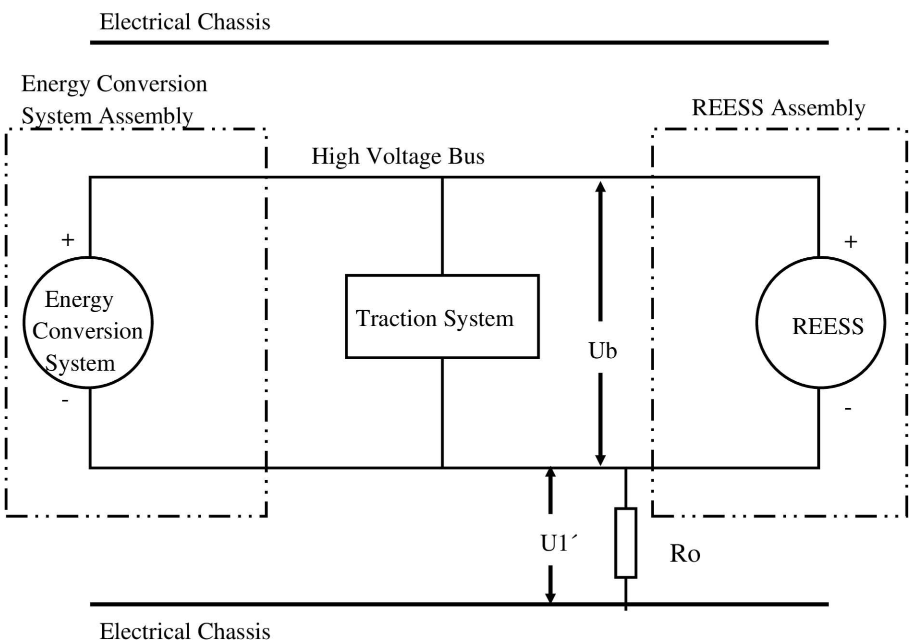
If U1 is greater than or equal to U2, insert a standard known resistance (Ro) between the negative side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage (U1') between the negative side of the high voltage bus and the electrical chassis (see Figure 2).

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

$$Ri = Ro*Ub*(1/U1' - 1/U1)$$

Figure 2

Measurement of U1'



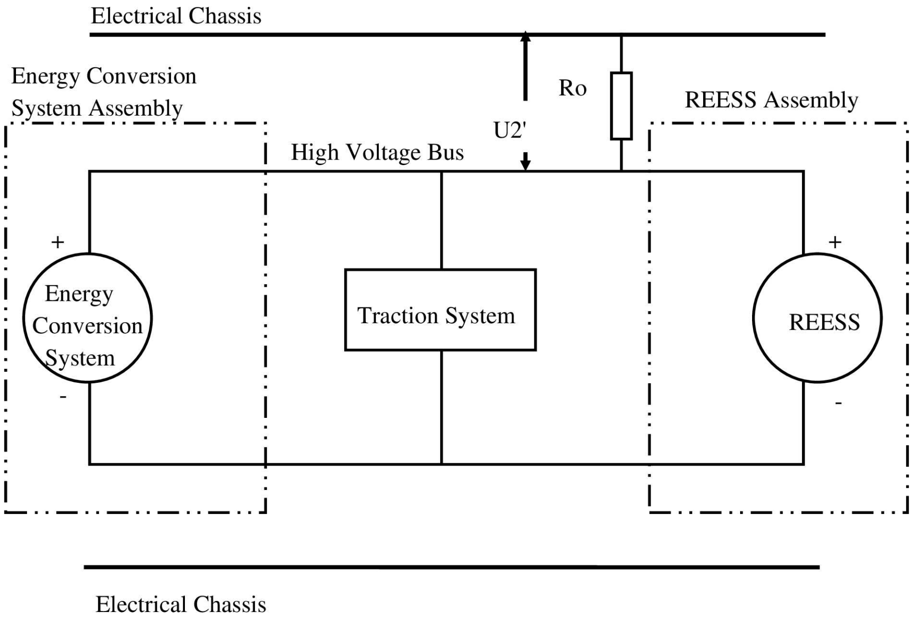
If U2 is greater than U1, insert a standard known resistance (Ro) between the positive side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage (U2') between the positive side of the high voltage bus and the electrical chassis (see Figure 3). Calculate the electrical isolation (Ri) according to the formula shown. Divide this electrical isolation value (in Ω) by the nominal operating voltage of the high voltage bus (in volts).

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

$$Ri = Ro*Ub*(1/U2' - 1/U2)$$

Figure 3

Measurement of U2’



2.2.3.5. Fifth step

The electrical isolation value Ri (in Ω) divided by the working voltage of the high voltage bus (in volts) results in the isolation resistance (in Ω/V).

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

ANNEX 5B

Isolation resistance measurement method for component based tests of a REESS

1. Measurement method

The isolation resistance measurement shall be conducted by selecting an appropriate measurement method from among those listed in paragraphs 1.1. through 1.2. of this Annex, depending on the electrical charge of the live parts or the isolation resistance, etc.

Megohmmeter or oscilloscope measurements are appropriate alternatives to the procedure described below for measuring isolation resistance. In this case, it may be necessary to deactivate the on-board isolation resistance monitoring system.

The range of the electrical circuit to be measured shall be clarified in advance, using electrical circuit diagrams, etc. If the high voltage buses are galvanically isolated from each other, isolation resistance shall be measured for each electrical circuit.

If the operating voltage of the Tested-Device (U_b, Figure 1) cannot be measured (e.g. due to disconnection of the electric circuit caused by main contactors or fuse operation) the test may be performed with a modified test device to allow measurement of the internal voltages (upstream the main contactors).

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 isolation resistance monitoring system, necessary modification for conducting the measurement may be carried out by stopping the operation of the device concerned or removing it. Furthermore, when the device is removed, a set of drawings will be used to prove that the isolation resistance between the live parts and the ground connection designated by the manufacturer as a point to be connected to the electrical chassis when installed on the vehicle remains unchanged.

These modifications shall not influence the test results.

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

1.1. Measurement method using DC voltage from external sources

1.1.1. Measurement instrument

An isolation resistance test instrument capable of applying a DC voltage higher than the nominal voltage of the Tested-Device shall be used.

1.1.2. Measurement method

An insulation resistance test instrument shall be connected between the live parts and the ground connection. Then, the isolation resistance shall be measured.

If the system has several voltage ranges (e.g. because of boost converter) in a 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 ground connection can be measured separately by applying at least half of their own working voltage with those component disconnected.

1.2. Measurement method using the Tested-Device as DC voltage source

1.2.1. Test conditions

The voltage level of the Tested-Device throughout the test shall be at least the nominal operating voltage of the Tested-Device.

1.2.2. Measurement instrument

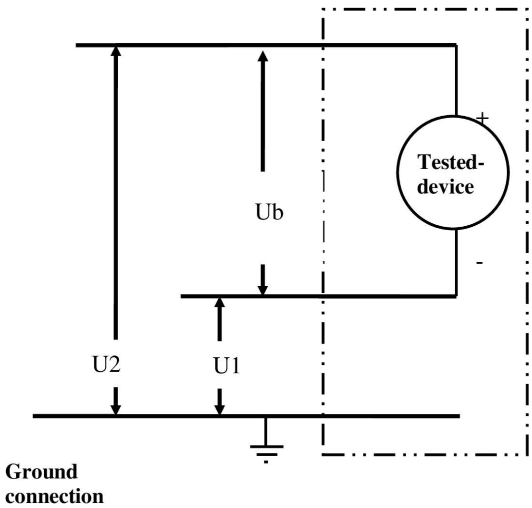
The voltmeter used in this test shall measure DC values and shall have an internal resistance of at least 10 MΩ.

1.2.3. Measurement method

1.2.3.1. First step

The voltage is measured as shown in Figure 1 and the operating voltage of the Tested-Device (Ub, Figure 1) is recorded. Ub shall be equal to or greater than the nominal operating voltage of the Tested-Device.

Figure 1



1.2.3.2. Second step

Measure and record the voltage (U1) between the negative pole of the Tested-Device and the ground connection (Figure 1).

1.2.3.3. Third step

Measure and record the voltage (U2) between the positive pole of the Tested-Device and the ground connection (Figure 1).

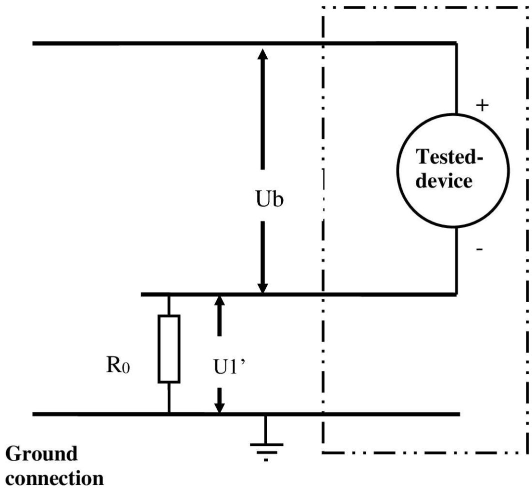
1.2.3.4. Fourth step

If U_1 is greater than or equal to U_2, insert a standard known resistance (Ro) between the negative pole of the Tested-Device and the ground connection. With Ro installed, measure the voltage (U_1') between the negative pole of the Tested-Device and the ground connection (see Figure 2).

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

$$Ri = Ro*U_b*(1/U_1' - 1/U_1)$$

Figure 2

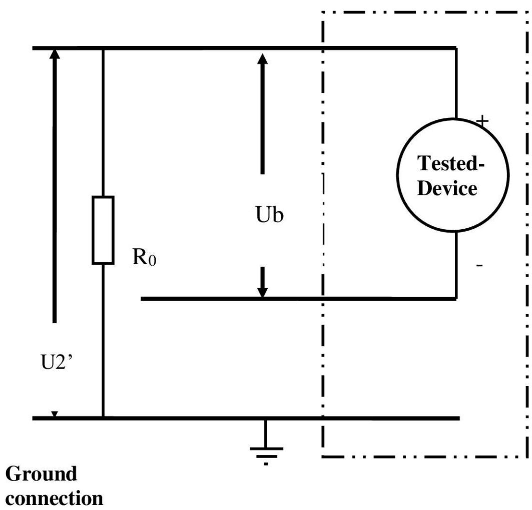


If U_2 is greater than U_1, insert a standard known resistance (Ro) between the positive pole of the Tested-Device and the ground connection. With Ro installed, measure the voltage (U_2’) between the positive pole of the Tested-Device and the ground connection (see Figure 3).

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

$$Ri = Ro*Ub*(1/U_2' - 1/U_2)$$

Figure 3



1.2.3.5. Fifth step

The electrical isolation value Ri (in Ω) divided by the nominal voltage of the Tested-Device (in volts) results in the isolation resistance (in Ω/V).

Note : The standard known resistance Ro (in Ω) should be the value of the minimum required isolation resistance (in Ω/V) multiplied by the nominal voltage of the Tested-Device plus/minus 20 per cent (in V). Ro is not required to be precisely this value since the equations are valid for any Ro; however, a Ro value in this range should provide good resolution for the voltage measurements.

ANNEX 6

Confirmation method for the function of an on-board isolation resistance monitoring system

The on-board isolation resistance monitoring system shall be tested using the following procedure:

(a) Determine the isolation resistance, Ri, of the electric power train with the electrical isolation monitoring system using the procedure outlined Annex 5A.

(b) If the minimum isolation resistance value required in accordance with paragraphs 5.1.3.1. or 5.1.3.2. is 100 Ω/V, insert a resistor with resistance Ro between either side of the high voltage bus that exhibit lower value in U_1 or U_2 measured in accordance with paragraph 2.2.3. of Annex 5A and the electrical chassis. The magnitude of the resistor, Ro, shall be such that:

$$1/(1/(95xU) - 1/Ri) \leq Ro < 1/(1/(100xU) - 1/Ri)$$

where U is the working voltage of the electric power train.

(c) If the minimum isolation resistance value required in accordance with paragraphs 5.1.3.1. or 5.1.3.2. is 500 Ω/V, insert a resistor with resistance Ro between either side of the high voltage bus that exhibit lower value in U_1 or U_2 measured in accordance with paragraph 2.2.3. of Annex 5A and the electrical chassis. The magnitude of the resistor, Ro, shall be such that:

$$1/(1/(475xU) - 1/Ri) \leq Ro < 1/(1/(500xU) - 1/Ri)$$

where U is the working voltage of the electric power train.

ANNEX 7A

Verification method for testing authorities confirming document based isolation resistance compliance of electrical design of the vehicle after water exposure

This annex describes the applicable requirements when certifying the manufacturer's high voltage equipment or system components against adverse water effects rather than a physical test. As a general rule, the electrical design or components of the vehicles shall comply with the requirements as specified in paragraphs "5.1.1. Protection against direct contact", "5.1.2. Protection against indirect contact", and "5.1.3. Isolation resistance" respectively and this will be separately verified by the testing authority. Vehicle manufacturers shall provide information to testing authorities to identify, as a point of reference, the mounting location for each high-voltage component in/on the vehicle.

1. Documentation shall contain the following information:

   (a) on how the manufacturer tested isolation resistance compliance of electrical design of the vehicle by using fresh water;

   (b) on how, after the test had been carried out, the high-voltage component or system was inspected for ingress of water and how, depending on its mounting location, each high voltage component/system met the appropriate degree of protection against water.

2. The testing authority will verify and confirm the authenticity of documented conditions that have been observed, and should have been complied with, during the process of certification by manufacturer:

2.1. It is permitted that, during the test, the moisture contained inside the enclosure is partly condensed. The dew which may be deposited is not considered as ingress of water. For the purpose of the tests, the surface area of the tested high-voltage component or system is calculated with an accuracy of 10 per cent. If possible, the tested high-voltage component or system is run energized. If the tested high-voltage component or system is energized, adequate safety precautions are taken.

2.2. For electrical components, externally attached (e.g. in engine compartment), open underneath, both exposed or protected locations, the testing authority shall verify, with a view to confirming the compliance, whether the test is conducted by spraying the high-voltage component or system from all practicable directions with a stream of water from a standard test nozzle as shown in Figure 1. The following parameters are observed during the test in particular:

   (a) Nozzle internal diameter: 6.3 mm;

   (b) Delivery rate: 11.9 – 13.2 l/min;

   (c) Water pressure at the nozzle: approximately 30 kPa (0.3 bar);

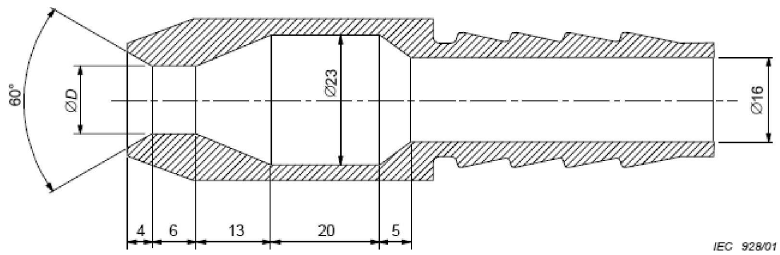
   (d) Test duration per m^2 of surface area of the tested high-voltage component or system: 1 min;

   (e) Minimum test duration: 3 min;

   (f) Distance from nozzle to tested high-voltage component or system surface: approximately 3 m (this distance may be reduced, if necessary to ensure proper wetting when spraying upwards).

Figure 1

Standard Nozzle for the Test



Dimensions in millimetres

D is 6.3 mm as specified in (a) above.

2.3. For electrical components, externally attached (e.g. in engine compartment), covered from underneath, the testing authority shall verify, with a view to confirming the compliance, whether:

(a) The cover protects the component against direct spray water from underneath and is not visible;

(b) The test is conducted by using splashing test nozzle as shown in Figure 2;

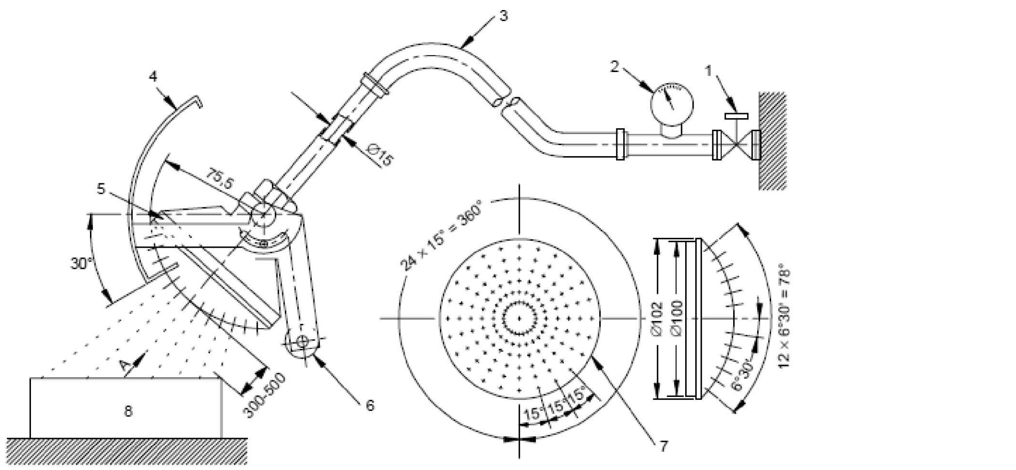
(c) The moving shield is removed from the spray nozzle and the machine is sprayed from all practicable directions;

(d) The water pressure is adjusted to give a delivery rate of (10 ± 0.5) l/min (pressure approximately 80 kPa to 100 kPa (0.8 bar to 1.0 bar));

(e) The test duration is 1 min/m² of calculated surface area of the machine (excluding any mounting surface and cooling fin) with a minimum duration of 5 min.

Figure 2

Splashing Test Nozzle



Dimensions in millimetres

Viewed according to arrow A (with shield removed)

IEC 927/01

Note:

1.	Cock	7.	Spray nozzle – brass with 121 holes Ø 0,5:
2.	Pressure gauge	1.	hole in centre
3.	Hose	2.	inner circle of 12 holes at 30° pitch

4. Moving shield – aluminium
5. Spray nozzle
6. Counter weight
7. outer circle of 24 holes at 15° pitch
8. Machine under test

3. The entire high voltage system or each component is checked to comply with the isolation resistance requirement in paragraph 5.1.3. with the following conditions:

   (a) The electric chassis shall be simulated by an electric conductor, e.g. a metal plate, and the components are attached with their standard mounting devices to it;

   (b) Cables, where provided, shall be connected to the component.

4. The parts designed not to be wet during operation are not allowed to be wet and no accumulation of water which could have reached them is tolerated inside the high-voltage component or system.

ANNEX 7B

Vehicle-based test procedure for protection against water effects

1. Washing

This test is intended to simulate the normal washing of vehicles, but not specific cleaning using high water pressure or underbody washing.

The areas of the vehicle regarding this test are border lines, i.e. a seal of two parts such as flaps, glass seals, outline of opening parts, outline of front grille and seals of lamps.

All border lines shall be exposed and followed in all directions with the water stream using a hose nozzle and conditions in accordance with IPX5 as specified in Annex 7A.

2. Driving through standing water

The vehicle shall be driven in a wade pool, with 10 cm water depth, over a distance of 500 m at a speed of 20 km/h, in a time of approximately 1.5 min. If the wade pool used is less than 500 m in length, then the vehicle shall be driven through it several times. The total time, including the periods outside the wade pool, shall be less than 10 min.

ANNEX 8

Determination of hydrogen emissions during the charge procedures of the REESS

1. Introduction

This annex describes the procedure for the determination of hydrogen emissions during the charge procedures of the REESS of all road vehicles, according to paragraph 5.4. of this Regulation.

2. Description of test

The hydrogen emission test (Figure 1 of Annex 8) is conducted in order to determine hydrogen emissions during the charge procedures of the REESS with the charger. The test consists in the following steps:

(a) Vehicle/REESS preparation;

(b) Discharge of the REESS;

(c) Determination of hydrogen emissions during a normal charge;

(d) Determination of hydrogen emissions during a charge carried out with the charger failure.

3. Tests

3.1. Vehicle based test

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

3.1.2. If the REESS is used at a temperature above the ambient temperature, the operator shall follow the manufacturer's procedure in order to keep the REESS temperature in normal functioning range.

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

3.2. Component based test

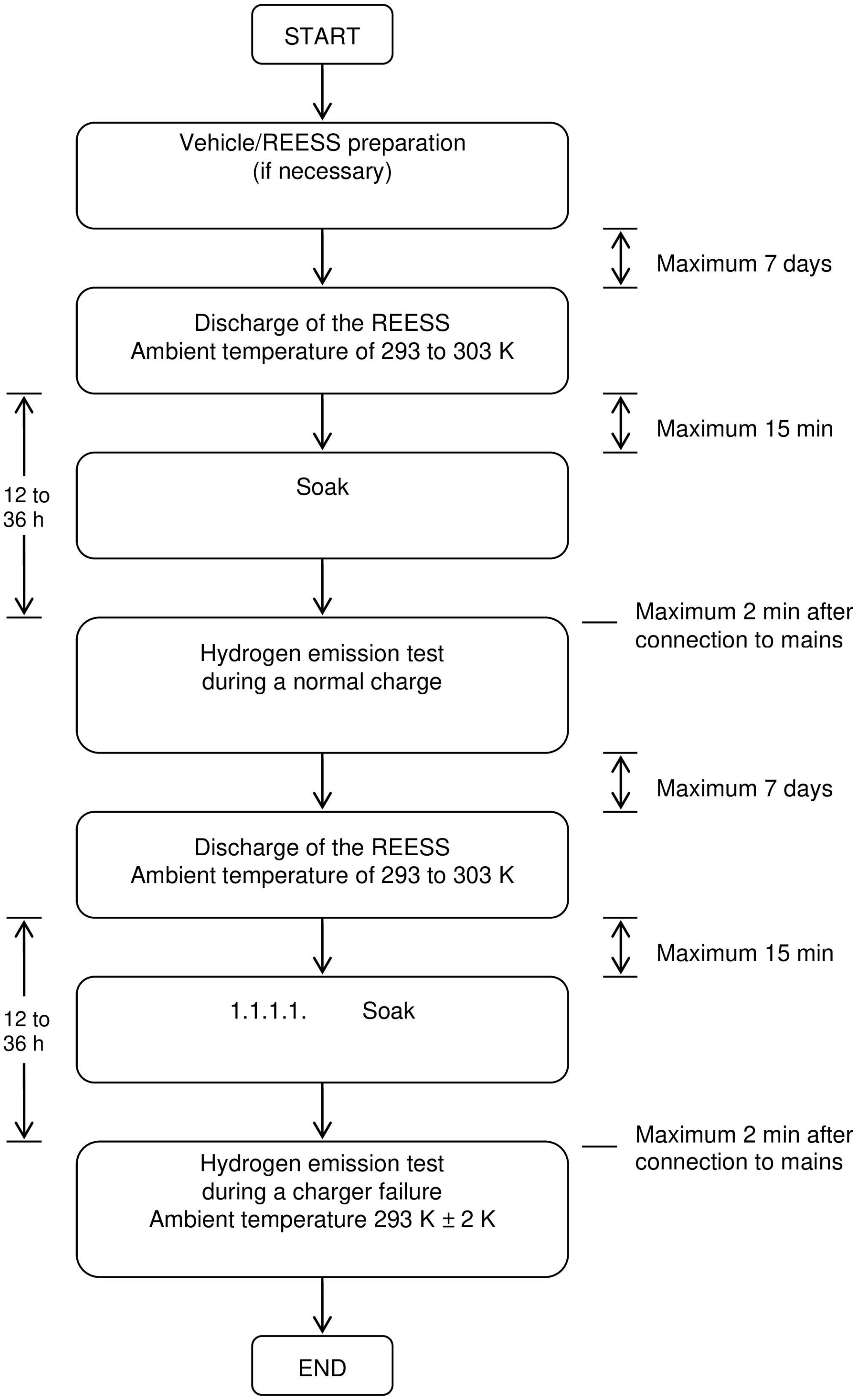
3.2.1. The REESS shall be in good mechanical condition and have been subject to minimum of 5 standard cycles (as specified in Annex 9, Appendix 1).

3.2.2. If the REESS is used at a temperature above the ambient temperature, the operator shall follow the manufacturer's procedure in order to keep the REESS temperature in its normal functioning range.

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

Figure 1

Determination of hydrogen emissions during the charge procedures of the REESS



4. Test equipment for hydrogen emission test

4.1. Chassis dynamometer

The chassis dynamometer shall meet the requirements of the 06 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/REESS under test. The vehicle/REESS 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 ±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 Annex 8, Appendix 1.

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

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 8, 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 ± 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 ± 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 ± 0.2 m.

4.4.2. The temperatures in the proximity of the cells 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 ±1.0 K and the temperature shall be capable of being resolved to ±0.1 K.

4.4.5. The recording or data processing system shall 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 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 ±2 hPa and the pressure shall be capable of being resolved to ±0.2 hPa.

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

4.6. Voltage and current intensity recording

4.6.1. The 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 ±1 V and the voltage shall be capable of being resolved to ±0.1 V.

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

4.6.4. The recording or data processing system shall be capable of resolving time to ±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^3/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_1 equivalent; < 1 ppm CO; < 400 ppm CO_2; < 0.1 ppm NO); oxygen content between 18 and 21 per cent by volume,

(b) Hydrogen (H_2), 99.5 per cent minimum purity.

4.8.2. Calibration and span gases shall contain mixtures of hydrogen (H_2) 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 Annex 8, 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/REESS preparation;

(b) Discharge of the REESS;

(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 charger failure.

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

5.1. Vehicle based test

5.1.1. Vehicle preparation

The ageing of REESS 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.

5.1.1.1. Discharges and initial charges of the REESS

The procedure starts with the discharge of the REESS 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.

5.1.1.2. Initial charge of the REESS

The charge is carried out:

(a) With the charger;

(b) In an ambient temperature between 293 K and 303 K.

The procedure excludes all types of external chargers.

The end of REESS charge criteria corresponds to an automatic stop given by the 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.

5.1.1.3. Procedure from paragraphs 5.1.1.1. and 5.1.1.2. shall be repeated two times.

5.1.2. Discharge of the REESS

The REESS is discharged while driving on the test track or on a chassis dynamometer at a steady speed of 70 per cent ± 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.

5.1.3. Soak

Within fifteen minutes of completing the battery discharge operation specified in paragraph 5.1.2., 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 K ± 2 K.

5.1.4. Hydrogen emission test during a normal charge

5.1.4.1. 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.

5.1.4.2. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.

5.1.4.3. 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.

5.1.4.4. The vehicle shall be connected to the mains. The REESS is charged according to normal charge procedure as specified in paragraph 5.1.4.7. below.

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

5.1.4.6. 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. of this annex). The ambient enclosure temperature T shall not be less than 291 K and no more than 295 K during the normal charge period.

5.1.4.7. Procedure of normal charge

The normal charge is carried out with the 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 REESS charge criteria corresponds to an automatic stop given by the 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.

5.1.4.8. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.

5.1.4.9. 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 Annex 8 paragraph 5.1.4.6. of this annex. 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 Annex 8, paragraph 6.

5.1.5. Hydrogen emission test with the charger failure

5.1.5.1. Within seven days maximum after having completed the prior test, the procedure starts with the discharge of the REESS of the vehicle according to Annex 8, paragraph 5.1.2.

5.1.5.2. The steps of the procedure in Annex 8, paragraph 5.1.3. of this annex shall be repeated.

5.1.5.3. 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.

5.1.5.4. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.

5.1.5.5. 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.

5.1.5.6. The vehicle shall be connected to the mains. The REESS is charged according to failure charge procedure as specified in paragraph 5.1.5.9. below.

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

5.1.5.8. 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 (Annex 8, 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.

5.1.5.9. Procedure of charging failure

The charging failure is carried out with the suitable charger and consists of the following steps:

(a) Charging at constant power during t'_1;

(b) Charging at maximum current as recommended by the manufacturer during 30 minutes. During this phase, the charger shall supply maximum current as recommended by the manufacturer.

5.1.5.10. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.

5.1.5.11. The end of test period occurs t'_1 + 30 minutes after the beginning of the initial sampling, as specified in paragraph 5.1.5.8. above. 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 Annex 8, paragraph 6.

5.2. Component based test

5.2.1. REESS preparation

The ageing of REESS shall be checked, to confirm that the REESS has performed at least 5 standard cycles (as specified in Annex 8, Appendix 1).

5.2.2. Discharge of the REESS

The REESS is discharged at 70 per cent ± 5 per cent of the nominal power of the system.

Stopping the discharge occurs when minimum SOC as specified by the manufacturer is reached.

5.2.3. Soak

Within 15 minutes of the end of the REESS discharge operation specified in paragraph 5.2.2. above, and before the start of the hydrogen emission test, the REESS shall be soaked at 293 K ± 2 K for a minimum period of 12 hours and a maximum of period of 36 hours.

5.2.4. Hydrogen emission test during a normal charge

5.2.4.1. Before the completion of the REESS's 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.

5.2.4.2. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.

5.2.4.3. At the end of the soak period, the REESS shall be moved into the measuring chamber.

5.2.4.4. The REESS shall be charged in accordance with the normal charge procedure as specified in paragraph 5.2.4.7. below.

5.2.4.5. The chamber shall be closed and sealed gas-tight within two minutes of the electrical interlock of the normal charge step.

5.2.4.6. The start of a normal charge for hydrogen emission test period shall begin 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 (Annex 8, 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.

5.2.4.7. Procedure of normal charge

The normal charge is carried out with a suitable 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 corresponding to that used during equalisation charging.

The end of REESS charge criteria corresponds to an automatic stop given by the 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 by a suitable instrumentation that the REESS is not yet fully charged.

5.2.4.8. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.

5.2.4.9. 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 5.2.4.6. above. 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 in Annex 8, paragraph 6.

5.2.5. Hydrogen emission test with the charger failure

5.2.5.1. The test procedure shall start within a maximum of seven days after having completed the test in paragraph 5.2.4. above, the procedure shall start with the discharge of the REESS of the vehicle in accordance with paragraph 5.2.2. above.

5.2.5.2. The steps of the procedure in paragraph 5.2.3. above shall be repeated.

5.2.5.3. 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.

5.2.5.4. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.

5.2.5.5. At the end of the soak the REESS shall be moved into the measuring chamber.

5.2.5.6. The REESS shall be charged according to the failure charge procedure as specified in paragraph 5.2.5.9. below.

5.2.5.7. The chamber shall be closed and sealed gas-tight within two minutes from electrical interlock of the failure charge step.

5.2.5.8. 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 (Annex 8, 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.

5.2.5.9. Procedure of charging failure

The charging failure is carried out with a suitable charger and consists of the following steps:

(a) Charging at constant power during t'_1,

(b) Charging at maximum current as recommended by the manufacturer during 30 minutes. During this phase, the charger shall supply maximum current as recommended by the manufacturer.

5.2.5.10. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.

5.2.5.11. The end of test period occurs $t'_1 + 30$ minutes after the beginning of the initial sampling, as specified in paragraph 5.2.5.8. above. 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. below.

6. Calculation

The hydrogen emission tests described in paragraph 5. above 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:

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

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 REESS are:

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

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

Annex 8 - 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 ±0.5 per cent of the reported value.

2.1.2. The net internal volume is determined by subtracting 1.42 m^3 from the internal volume of the chamber. Alternatively the volume of the test vehicle with the luggage compartment and windows open or REESS may be used instead of the 1.42 m^3.

2.1.3. The chamber shall be checked as in Annex 8, 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 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. above. Ambient temperature shall be maintained at 293 K ± 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 Annex 8, 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. above) 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 K ± 2 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 ±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 above and the formula in paragraph 2.4. below, the mass of hydrogen in the enclosure is calculated. This shall be within ±2 per cent of the mass of hydrogen measured in paragraph 2.3.6. above.

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. below, the hydrogen mass is then calculated from the readings taken in paragraphs 2.3.7 and 2.3.9. above. This mass may not differ by more than 5 per cent from the hydrogen mass given by paragraph 2.3.8. above.

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.

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

Where:

M_{H2} = hydrogen mass, in grams

C_{H2} = measured hydrogen concentration into the enclosure, in ppm volume

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

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 Annex 8, paragraph 4.8.2.

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 8 - 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.

   REESS:

   (a) Trade name or mark of theREESS;

   (b) Indication of all types of electrochemical couples used;

   (c) Number of REESS cells;

   (d) Number of REESS subsystems;

   (e) Nominal voltage of the REESS (V);

   (f) REESS energy (kWh);

   (g) Gas combination rate (in per cent);

   (h) Type(s) of ventilation for REESS subsystem(s);

   (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.

ANNEX 9

REESS test procedures

Annex 9 - Appendix 1

Procedure for conducting a standard cycle

A standard cycle shall start with a standard discharge followed by a standard charge. The standard cycle shall be conducted at an ambient temperature of 20 ± 10 °C.

Standard discharge:

Discharge rate:	The discharge procedure including termination criteria shall be defined by the manufacturer. If not specified, then it shall be a discharge with 1C current for a complete REESS and REESS subsystems.
Discharge limit (end voltage):	Specified by the manufacturer

For a complete vehicle, discharge procedure using a dynamometer shall be defined by the manufacturer. Discharge termination will be according to vehicle controls.

Rest period after discharge: Minimum 15 min

Standard charge:

The charge procedure shall be defined by the manufacturer. If not specified, then it shall be a charge with C/3 current. Charging is continued until normally terminated. Charge termination shall be according to paragraph 2. of Annex 9, Appendix 2 for REESS or REESS subsystem.

For a complete vehicle that can be charged by an external source, charge procedure using an external electric power supply shall be defined by the manufacturer. For a complete vehicle that can be charged by on-board energy sources, a charge procedure using a dynamometer shall be defined by the manufacturer. Charge termination will be according to vehicle controls.

Annex 9 – Appendix 2

Procedure for SOC adjustment

1. The adjustment of SOC shall be conducted at an ambient temperature of 20 ± 10 °C for vehicle-based tests and 22 ± 5 °C for component-based tests.

2. The SOC of the Tested-Device shall be adjusted according to one of the following procedures as applicable. Where different charging procedures are possible, the REESS shall be charged using the procedure which yields the highest SOC:

   (a) For a vehicle with a REESS designed to be externally charged, the REESS shall be charged to the highest SOC in accordance with the procedure specified by the manufacturer for normal operation until the charging process is normally terminated;

   (b) For a vehicle with a REESS designed to be charged only by an energy source on the vehicle, the REESS shall be charged to the highest SOC which is achievable with normal operation of the vehicle. The manufacturer shall advise on the vehicle operation mode to achieve this SOC;

   (c) In case that the REESS or REESS subsystem is used as the Tested-Device, the Tested-Device shall be charged to the highest SOC in accordance with the procedure specified by the manufacturer for normal use operation until the charging process is normally terminated. Procedures specified by the manufacturer for manufacturing, service or maintenance may be considered as appropriate if they achieve an equivalent SOC as for that under normal operating conditions. In case the Tested-Device does not control SOC by itself, the SOC shall be charged to not less than 95 per cent of the maximum normal operating SOC defined by the manufacturer for the specific configuration of the Tested-Device.

3. When the vehicle or REESS subsystem is tested, the SOC shall be no less than 95 per cent of the SOC according to paragraphs 1. and 2. above for REESS designed to be externally charged and shall be no less than 90 per cent of SOC according to paragraphs 1. and 2. above for REESS designed to be charged only by an energy source on the vehicle. The SOC will be confirmed by a method provided by the manufacturer.

ANNEX 9A

Vibration test

1. Purpose

The purpose of this test is to verify the safety performance of the REESS under a vibration environment which the REESS will likely experience during the normal operation of the vehicle.

2. Installations

2.1. This test shall be conducted either with the complete REESS or with REESS subsystem(s) If the manufacturer chooses to test with REESS subsystem(s), the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions. If the electronic management unit for the REESS is not integrated in the casing enclosing the cells, then the electronic management unit may be omitted from installation on the Tested-Device if so requested by the manufacturer.

2.2. The Tested-Device shall be firmly secured to the platform of the vibration machine in such a manner as to ensure that the vibrations are directly transmitted to the Tested-Device.

The Tested-Device should be mounted with its original mounting points, if those exist in the Tested-Device, as mounted in the vehicle.

3. Procedures

3.1. General test conditions

The following conditions shall apply to the Tested-Device:

(a) The test shall be conducted at an ambient temperature of 22 ± 5 °C;

(b) At the beginning of the test, the SOC shall be adjusted in accordance with Annex 9, Appendix 2;

(c) At the beginning of the test, all protection devices which affect the function(s) of the Tested-Device that are relevant to the outcome of the test shall be operational.

3.2. Test procedures

The Tested-Devices shall be subjected to a vibration having a sinusoidal waveform with a logarithmic sweep between 7 Hz and 50 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours in the vertical direction of the mounting orientation of the REESS as specified by the manufacturer.

The correlation between frequency and acceleration shall be as shown in Table 1:

Table 1

Frequency and acceleration

Frequency (Hz)	Acceleration (m/s2)
7 - 18	10
18 - 30	gradually reduced from 10 to 2
30 - 50	2

At the request of the manufacturer, a higher acceleration level as well as a higher maximum frequency may be used.

At the request of the manufacturer a vibration test profile determined by the vehicle-manufacturer, verified for the vehicle application and agreed with the Technical Service may be used as a substitute for the frequency - acceleration correlation of Table 1. The approval of a REESS tested according to this condition shall be limited to the installation for a specific vehicle type.

After the vibration, a standard cycle as described in Annex 9, Appendix 1 shall be conducted, if not inhibited by the Tested-Device.

The test shall end with an observation period of 1 h at the ambient temperature conditions of the test environment.

ANNEX 9B

Thermal shock and cycling test

1. Purpose

The purpose of this test is to verify the resistance of the REESS to sudden changes in temperature. The REESS shall undergo a specified number of temperature cycles, which start at ambient temperature followed by high and low temperature cycling. It simulates a rapid environmental temperature change which a REESS would likely experience during its life.

2. Installations

This test shall be conducted either with the complete REESS or with ~~related~~ REESS subsystem(s). If the manufacturer chooses to test with REESS subsystem(s), the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions. If the electronic management unit for the REESS is not integrated in the casing enclosing the cells, then the electronic management unit may be omitted from installation on the Tested-Device if so requested by the manufacturer.

3. Procedures

3.1. General test conditions

The following conditions shall apply to the Tested-Device at the start of the test:

(a) The SOC shall be adjusted in accordance with Annex 9, Appendix 2;

(b) All protection devices, which would affect the function of the Tested-Device and which are relevant to the outcome of the test shall be operational.

3.2. Test procedure

The Tested-Device shall be stored for at least six hours at a test temperature equal to 60 ± 2 °C or higher if requested by the manufacturer, followed by storage for at least six hours at a test temperature equal to -40 ± 2 °C or lower if requested by the manufacturer. The maximum time interval between test temperature extremes shall be 30 minutes. This procedure shall be repeated until a minimum of 5 total cycles are completed, after which the Tested-Device shall be stored for 24 hours at an ambient temperature of 22 ± 5 °C.

After the storage for 24 hours, a standard cycle as described in Annex 9, Appendix 1 shall be conducted, if not inhibited by the Tested-Device.

The test shall end with an observation period of 1 h at the ambient temperature conditions of the test environment.

ANNEX 9C

Mechanical shock

1. Purpose

The purpose of this test is to verify the safety performance of the REESS under inertial loads which may occur during a vehicle crash.

2. Installation

2.1. This test shall be conducted either with the complete REESS or with REESS subsystem(s). If the manufacturer chooses to test with REESS subsystem(s), the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions. If the electronic management unit for the REESS is not integrated in the casing enclosing the cells, then the electronic management unit may be omitted from installation on the Tested-Device if so requested by the manufacturer

2.2. The Tested-Device shall be connected to the test fixture only by the intended mountings provided for the purpose of attaching the REESS or REESS subsystem to the vehicle.

3. Procedures

3.1. General test conditions and requirements

The following condition shall apply to the test:

(a) The test shall be conducted at an ambient temperature of 20 ± 10 °C,

(b) At the beginning of the test, the SOC shall be adjusted in accordance with Annex 9, Appendix 2;

(c) At the beginning of the test, all protection devices which affect the function of the Tested-Device and which are relevant to the outcome of the test, shall be operational.

3.2. Test procedure

The Tested-Device shall be decelerated or accelerated in compliance with the acceleration corridors which are specified in Tables 1 to 3. The manufacturer shall decide whether the tests shall be conducted in either the positive or negative direction or both.

For each of the test pulses specified, a separate Tested-Device may be used.

The test pulse shall be within the minimum and maximum value as specified in Tables 1 to 3. A higher shock level and /or longer duration as described in the maximum value in Tables 1 to 3 can be applied to the Tested-Device if recommended by the manufacturer.

The test shall end with an observation period of 1 hour at the ambient temperature conditions of the test environment.

Figure 1

Generic description of test pulses

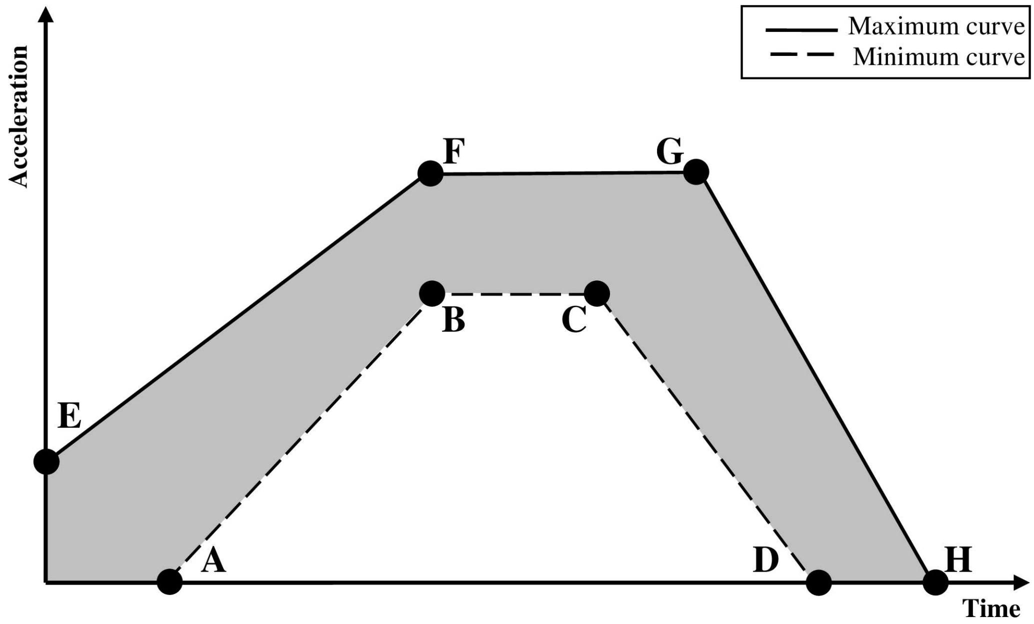


Table 1 for M_1, N_1 , O_1 and O_2 vehicles ([1]):

Point	Time (ms)	Acceleration (g)	
		Longitudinal	Transverse
A	20	0	0
B	50	20	8
C	65	20	8
D	100	0	0
E	0	10	4.5
F	50	28	15
G	80	28	15
H	120	0	0

Table 2 for M_2 and N_2 vehicles:

Point	Time (ms)	Acceleration (g)	
		Longitudinal	Transverse
A	20	0	0
B	50	10	5
C	65	10	5
D	100	0	0
E	0	5	2.5

([1]) For vehicles of category O_1 and O_2 at the request of the manufacturer the pulses defined in table 2 of Annex 9C paragraph 3.2 may be used if the maximum design speed of these vehicles of category O_1 and O_2 is limited to 100 km/h.

Point	Time (ms)	Acceleration (g)	
		Longitudinal	Transverse
F	50	17	10
G	80	17	10
H	120	0	0

Table 3 for M_3**,** N_3, O_3, O_4 vehicles:

Point	Time (ms)	Acceleration (g)	
		Longitudinal	Transverse
A	20	0	0
B	50	6,6	5
C	65	6,6	5
D	100	0	0
E	0	4	2.5
F	50	12	10
G	80	12	10
H	120	0	0

The test shall end with an observation period of 1 hour at the ambient temperature conditions of the test environment .

ANNEX 9D

Mechanical integrity

1. Purpose

The purpose of this test is to verify the safety performance of the REESS under contact loads which may occur during vehicle crash situation.

2. Installations

2.1. This test shall be conducted with either the complete REESS or with a related REESS subsystem(s) including the cells and their electrical connections. If the manufacturer chooses to test with related subsystem(s), the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions. If the electronic management unit for the REESS is not integrated in the casing enclosing the cells, then the electronic management unit may be omitted from installation on the Tested-Device if so requested by the manufacturer.

2.2. The Tested-Device shall be connected to the test fixture as recommended by the manufacturer.

3. Procedures

3.1. General test conditions

The following condition and requirements shall apply to the test:

(a) The test shall be conducted at an ambient temperature of 20 ± 10 °C;

(b) At the beginning of the test, the SOC shall be adjusted in accordance with Annex 9, Appendix 2;

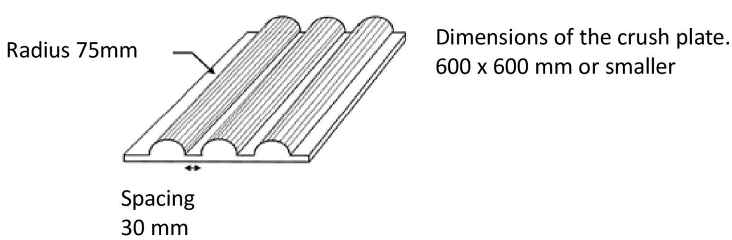
(c) At the beginning of the test, all internal and external protection devices which would affect the function of the Tested-Device and which are relevant to the outcome of the test shall be operational.

(d) In case where paragraph 6.4.2.1.2. is applied, vehicle body structure, electrical protection barriers, enclosures, or other mechanical functional devices providing protection against contact regardless of whether outside or inside of the REESS may be attached to the Tested-Device if so requested by the manufacturer. The manufacturer shall define the relevant parts used for the mechanical protection of the REESS. The test may be conducted with the REESS mounted to this vehicle structure in a way which is representative of its mounting in the vehicle.

3.2. Crush test

3.2.1. Crush force

The tested-Device shall be crushed between a resistance and a crush plate as described in figure 1 with a force of at least 100 kN, but not exceeding 105 kN, unless otherwise specified in accordance with Paragraph 6.4.2 of this Regulation, with an onset time less than 3 minutes and a hold time of at least 100 ms but not exceeding 10s.



A higher crush force, a longer onset time, a longer hold time, or a combination of these, may be applied at the request of the manufacturer.

The application of the force shall be decided by the manufacturer together with the technical service having consideration to the direction of travel of the REESS relative to its installation in the vehicle. The application force being applied; (a) horizontally and in the direction of travel of the REESS, and (b) horizontally and perpendicular to the direction of travel of the REESS. For each of the test directions specified, a separate test-device may be used.

The test shall end with an observation period of 1 h at the ambient temperature conditions of the test environment.

ANNEX 9E

Fire resistance

1. Purpose

The purpose of this test is to verify the resistance of the REESS, against exposure to fire from outside of the vehicle due to e.g. a fuel spill from a vehicle (either the vehicle itself or a nearby vehicle). This situation should leave the driver and passengers with enough time to evacuate.

2. Installations

2.1. This test shall be conducted either with the complete REESS or with REESS subsystem(s). If the manufacturer chooses to test with REESS subsystem(s), the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions. If the electronic management unit for the REESS is not integrated in the casing enclosing the cells, then the electronic management unit may be omitted from installation on the Tested-Device if so requested by the manufacturer. Where the relevant REESS subsystems are distributed throughout the vehicle, the test may be conducted on each relevant of the REESS subsystem.

3. Procedures

3.1. General test conditions

The following requirements and conditions shall apply to the test:

(a) The test shall be conducted at a temperature of at least 0 °C;

(b) At the beginning of the test, the SOC shall be adjusted in accordance with Annex 9, Appendix 2;

(c) At the beginning of the test, all protection devices which affect the function of the Tested-Device and are relevant for the outcome of the test shall be operational..

3.2. Test procedure

A vehicle based test or a component based test shall be performed at the discretion of the manufacturer:

3.2.1. Vehicle based test

The Tested-Device shall be mounted in a testing fixture simulating actual mounting conditions as far as possible; no combustible material should be used for this with the exception of material that is part of the REESS. The method whereby the Tested-Device is fixed in the fixture shall correspond to the relevant specifications for its installation in a vehicle. In the case of a REESS designed for a specific vehicle use, vehicle parts which affect the course of the fire in any way shall be taken into consideration.

3.2.2. Component based test

In case of component based test, the manufacturer may choose either gasoline pool fire test or LPG burner test.

The Tested-Device shall be placed on a grating table positioned above the pan, in an orientation according to the manufacturer's design intent.

The grating table shall be constructed by steel rods, diameter 6-10 mm, with 4-6 cm in between. If needed the steel rods could be supported by flat steel parts.

3.3. Gasoline pool fire test set up for both vehicle-based and component-based test.

The flame to which the Tested-Device is exposed shall be obtained by burning commercial fuel for positive-ignition engines (hereafter called "fuel") in a pan. The quantity of fuel shall be sufficient to permit the flame, under free-burning conditions, to burn for the whole test procedure.

The fire shall cover the whole area of the pan during whole fire exposure. The pan dimensions shall be chosen so as to ensure that the sides of the Tested-Device are exposed to the flame. The pan shall therefore exceed the horizontal projection of the Tested-Device by at least 20 cm, but not more than 50 cm. The sidewalls of the pan shall not project more than 8 cm above the level of the fuel at the start of the test.

3.3.1. The pan filled with fuel shall be placed under the Tested-Device in such a way that the distance between the level of the fuel in the pan and the bottom of the Tested-Device corresponds to the design height of the Tested-Device above the road surface at the unladen mass if paragraph 3.2.1. above is applied or approximately 50 cm if paragraph 3.2.2. above is applied. Either the pan, or the testing fixture, or both, shall be freely movable.

3.3.2. During phase C of the test, the pan shall be covered by a screen. The screen shall be placed 3 cm +/- 1 cm above the fuel level measured prior to the ignition of the fuel. The screen shall be made of a refractory material, as prescribed in Annex 9E - Appendix 1. There shall be no gap between the bricks and they shall be supported over the fuel pan in such a manner that the holes in the bricks are not obstructed. The length and width of the frame shall be 2 cm to 4 cm smaller than the interior dimensions of the pan so that a gap of 1 cm to 2 cm exists between the frame and the wall of the pan to allow ventilation. Before the test the screen shall be at least at the ambient temperature. The firebricks may be wetted in order to guarantee repeatable test conditions.

3.3.3. If the tests are carried out in the open air, sufficient wind protection shall be provided and the wind velocity at pan level shall not exceed 2.5 km/h.

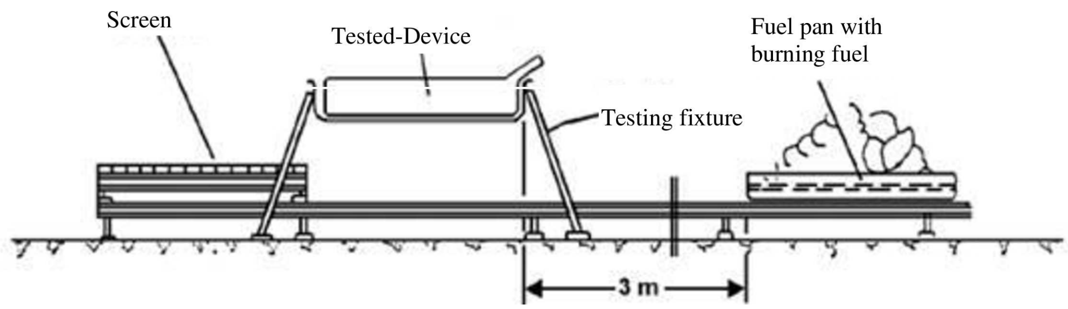
3.3.4. The test shall comprise of three phases B-D, if the fuel is at least at temperature of 20 °C. Otherwise the test shall comprise four phases A–D.

3.3.4.1. Phase A: Pre-heating (Figure 1)

The fuel in the pan shall be ignited at a distance of at least 3 m from the Tested-Device. After 60 seconds pre-heating, the pan shall be placed under the Tested-Device. If the size of the pan is too large to be moved without risking liquid spills etc. then the Tested-Device and test rig can be moved over the pan instead.

Figure 1

Phase A: Pre-heating

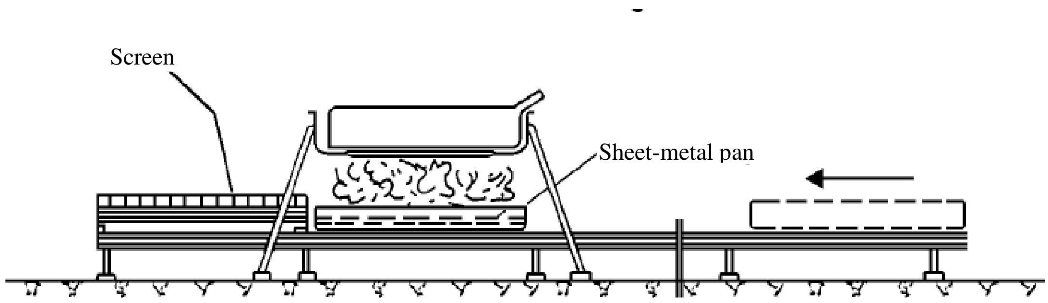


3.3.4.2. Phase B: Direct exposure to flame (Figure 2)

The Tested-Device shall be exposed to the flame from the freely burning fuel for 70 seconds.

Figure 2

Phase B: Direct exposure to flame



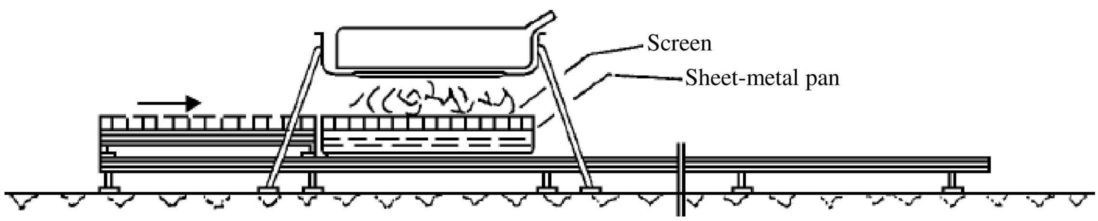
3.3.4.3. Phase C: Indirect exposure to flame (Figure 3)

As soon as phase B has been completed, the screen shall be placed between the burning pan and the Tested-Device. The Tested-Device shall be exposed to this reduced flame for a further 60 seconds.

Instead of conducting phase C of the test, phase B may at the manufacturer's discretion be continued for an additional 60 seconds.

Figure 3

Phase C: Indirect exposure to flame

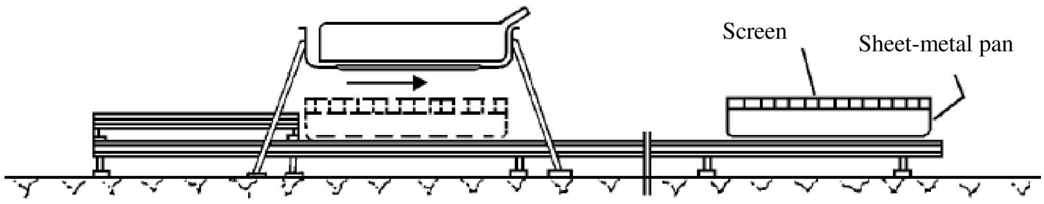


3.3.4.4. Phase D: End of test (Figure 4)

The burning pan covered with the screen shall be moved back to the position described in phase A. No extinguishing of the Tested-Device shall be done. After removal of the pan the Tested-Device shall be observed until such time as the surface temperature of the Tested-Device has decreased to ambient temperature or has been decreasing for a minimum of 3 hours.

Figure 4

Phase D: End of test



3.4. LPG burner fire test set up for component based test

3.4.1. The Tested-Device shall be placed on a test equipment, in the position that the manufacturer's design intends.

3.4.2. LPG burner shall be used to produce flame to which the Tested-Device is exposed. The height of the flame shall be about 60 cm or more, without the Tested-Device.

3.4.3. The flame temperature shall be measured continuously by temperature sensors. An average temperature shall be calculated, at least every second for the duration of the whole fire exposure, as the arithmetic average of temperatures measured by all temperature sensors fulfilling the location requirements described in paragraph 3.4.4.

3.4.4. All temperature sensors shall be installed at a height of 5 ± 1 cm below the lowest point of the Tested-Device's external surface when oriented as described in paragraph 3.4.1. At least one temperature sensor shall be located at the centre of Tested-Device, and at least four temperature sensors shall be located within 10 cm from the edge of the Tested-Device towards its centre with nearly equal distance between the sensors.

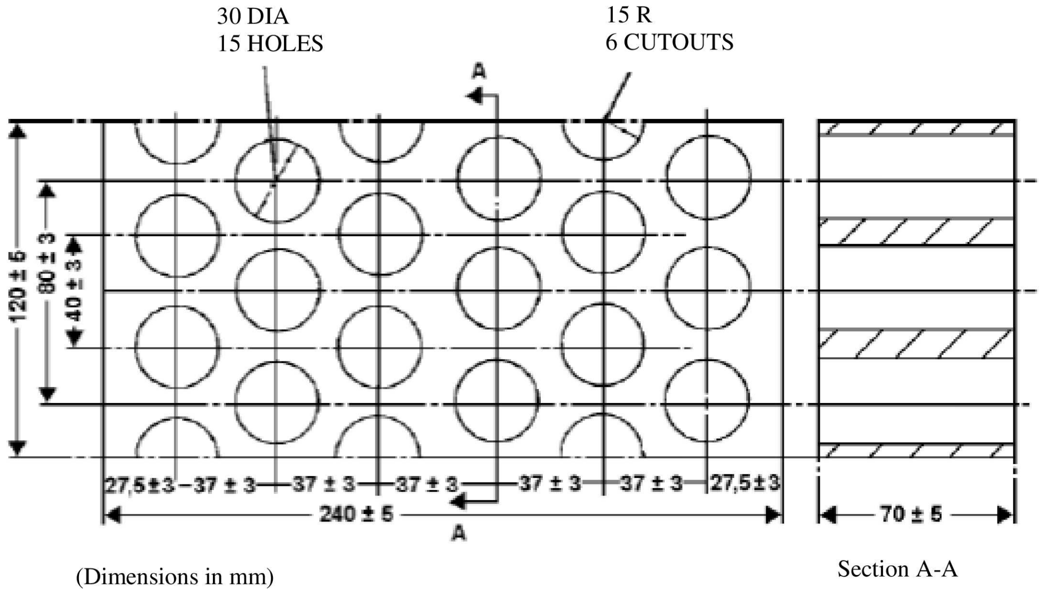
3.4.5. The bottom of Tested-Device shall be exposed to the even flame directly and entirely by fuel combustion. LPG burner flame shall exceed the horizontal projection of the Tested-Device by at least 20 cm.

3.4.6. An average temperature of 800 °C shall be reached within 30 seconds and maintained between 800°C and 1,100°C. The Tested-Device shall then be exposed to the frame for 2 minutes.

3.4.7. After direct exposure to flame the Tested-Device shall be observed until such time as the surface temperature of the Tested-Device has decreased to ambient temperature or has been decreasing for a minimum of 3 hours.

Annex 9E - Appendix 1

Dimension and technical data of firebricks



Fire resistance:	(Seger-Kegel) SK 30
Al2O3 content:	30 - 33 per cent
Open porosity (Po):	20 - 22 per cent vol.
Density:	1,900 - 2,000 kg/m3
Effective holed area:	44.18 per cent

ANNEX 9F

External short circuit protection

1. Purpose

The purpose of this test is to verify the performance of the short circuit protection to prevent the REESS from any further related severe events caused by short circuit current.

2. Installations

This test shall be conducted either with a complete vehicle or with the complete REESS or with the REESS subsystem(s). If the manufacturer chooses to test with REESS subsystem(s), the Tested-Device shall be able to deliver the nominal voltage of the complete REESS and the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions. If the electronic management unit for the REESS is not integrated in the casing enclosing the cells, then the electronic management unit may be omitted from installation on the Tested-Device if so requested by the manufacturer. For a test with a complete vehicle, the manufacturer may provide information to connect a breakout harness to a location just outside the REESS that would permit applying a short circuit to the REESS.

3. Procedures

3.1. General test conditions

The following condition shall apply to the test:

(a) The test shall be conducted at an ambient temperature of 20 ± 10 °C or at higher temperature if requested by the manufacturer;

(b) At the beginning of the test, the SOC shall be adjusted in accordance with Annex 9, Appendix 2;

(c) At the beginning of the test, all protection devices which would affect the function of the Tested-Device and which are relevant to the outcome of the test shall be operational.

(d) For testing with a complete vehicle, a breakout harness is connected to the manufacturer specified location and vehicle protection systems relevant to the outcome of the test shall be operational.

3.2. Short circuit

At the start of the test all relevant main contactors for charging and discharging shall be closed to represent the active driving possible mode as well as the mode to enable external charging. If this cannot be completed in a single test, then two or more tests shall be conducted.

For testing with a complete REESS or REESS subsystem(s), the positive and negative terminals of the Tested-Device shall be connected to each other to produce a short circuit. The connection used for this purpose shall have a resistance not exceeding 5 mΩ.

For testing with a complete vehicle, the short circuit is applied through the breakout harness. The connection used for creating the short circuit (including the cabling) shall have a resistance not exceeding 5 mΩ.

The short circuit condition shall be continued until the protection function operation of the REESS terminate the short circuit current is confirmed, or for at least one hour after the temperature measured on the casing of the Tested-Device has stabilised, such that the temperature gradient varies by a less than 4 °C through 2 hour.

3.3. Standard cycle and observation period

Directly after the termination of the short circuit a standard cycle as described in Annex 9, Appendix 1 shall be conducted, if not inhibited by the Tested-Device.

The test shall end with an observation period of 1 h at the ambient temperature conditions of the test environment.

ANNEX 9G

Overcharge protection

1. Purpose

The purpose of this test is to verify the performance of the overcharge protection to prevent the REESS from any further related severe events caused by a too high SOC.

2. Installations

This test shall be conducted, under standard operating conditions, either with a complete vehicle or with the complete REESS Ancillary systems that do not influence the test results may be omitted from the Tested-Device.

The test may be performed with a modified Tested-Device these modifications shall not influence the test results.

3. Procedures

3.1. General test conditions

The following requirements and conditions shall apply to the test:

(a) The test shall be conducted at an ambient temperature of 20 ± 10 °C or at higher temperature if requested by the manufacturer;

(b) The SOC of REESS shall be adjusted around the middle of normal operating range by normal operation recommended by the manufacturer such as driving the vehicle or using an external charger. The accurate adjustment is not required as long as the normal operation of the REESS is enabled;

(c) For vehicle-based test of vehicles with on-board energy conversion systems (e.g. internal combustion engine, fuel cell, etc.), fill the fuel to allow the operation of such energy conversion systems;

(d) At the beginning of the test, all protection devices which would affect the function of the Tested-Device and which are relevant to the outcome of the test shall be operational. All relevant main contactors for charging shall be closed.

3.2. Charging

The procedure for charging the REESS for vehicle-based test shall be in accordance with paragraphs 3.2.1. and 3.2.2. and shall be selected as appropriate for the relevant mode of vehicle operation and the functionality of the protection system. Alternatively, the procedure for charging the REESS for vehicle-based test shall be in accordance with paragraph 3.2.3. For component-based test, the charging procedure shall be in accordance with paragraph 3.2.4.

3.2.1. Charge by vehicle operation.

This procedure is applicable to the vehicle-based tests in active driving possible mode:

(a) For vehicles that can be charged by on-board energy sources (e.g. energy recuperation, on-board energy conversion systems), the vehicle shall be driven on a chassis dynamometer. The vehicle operation on a chassis dynamometer (e.g. simulation of continuous down-hill driving) that will deliver as high charging current as reasonably achievable shall be determined, if necessary, through consultation with the manufacturer.

(b) The REESS shall be charged by the vehicle operation on a chassis dynamometer in accordance with paragraph 3.2.1.(a). The vehicle operation on the chassis dynamometer shall be terminated when the vehicle's overcharge protection controls terminates the REESS charge current or the temperature of the REESS is stabilized such that the temperature varies by a gradient of less than 2 °C through 1 hour. Where an automatic interrupt function vehicle's overcharge protection control fails to operate, or if there is no such control function, the charging shall be continued until the REESS temperature reaches 10 °C above its maximum operating temperature specified by the manufacturer.

(c) Immediately after the termination of charging, one standard cycle as described in Annex 9, Appendix 1 shall be conducted, if it is not prohibited by the vehicle, with vehicle operation on a chassis dynamometer.

3.2.2. Charge by external electricity supply (vehicle-based test).

This procedure is applicable to vehicle-based test for externally chargeable vehicles:

(a) The vehicle inlet for normal use, if it exists, shall be used for connecting the external electricity supply equipment. The charge control communication of the external electricity supply equipment shall be altered or disabled to allow the charging specified in paragraph 3.2.2.(b) below;

(b) The REESS shall be charged by the external electricity supply equipment with the maximum charge current specified by the manufacturer. The charging shall be terminated when the vehicle's overcharge protection control terminates the REESS charge current. Where vehicle's overcharge protection control fails to operate, or if there is no such control, the charging shall be continued until the REESS temperature reaches 10 °C above its maximum operating temperature specified by the manufacturer. In the case where charge current is not terminated and where the REESS temperature remains less than 10 °C above the maximum operating temperature, vehicle operation shall be terminated 12 hours after the start of charging by external electricity supply equipment;

(c) Immediately after the termination of charging, one standard cycle as described in Annex 9, Appendix 1 shall be conducted, if it is not prohibited by the vehicle, with vehicle operation on a chassis dynamometer for discharging and with external electricity supply equipment for charging.

3.2.3. Charge by connecting breakout harness (vehicle-based test).

This procedure is applicable to vehicle-based tests for both externally chargeable vehicles and vehicles that can be charged only by on-board energy sources and for which the manufacturer provides information to connect a breakout harness to a location just outside the REESS that permits charging of the REESS:

(a) The breakout harness is connected to the vehicle as specified by the manufacturer. The trip current/voltage setting of the external charge-discharge equipment shall be at least 10 per cent higher than the current/voltage limit of the Tested-Device. The external electricity supply equipment is connected to the breakout harness. The REESS shall be charged by the external electricity power supply with the maximum charge current specified by the manufacturer;

(b) The charging shall be terminated when the vehicle's overcharge protection control terminates the REESS charge current. Where vehicle's overcharge protection control fails to operate, or if there is no such control, the charging shall be continued until the REESS temperature is 10 °C above its maximum operating temperature specified by the manufacturer. In the case where charge current is not terminated and where the REESS temperature remains less than 10 °C above the maximum operating temperature, vehicle operation shall be terminated 12 hours after the start of charging by external electricity supply equipment;

(c) Immediately after the termination of charging, one standard cycle as described in Annex 9, Appendix 1 (for a complete vehicle) shall be conducted, if it is not prohibited by the vehicle.

3.2.4. Charge by external electricity supply (component-based test).

This procedure is applicable to component-based test:

(a) The external charge/discharge equipment shall be connected to the main terminals of the REESS. The charge control limits of the test equipment shall be disabled;

(b) The REESS shall be charged by the external charge/discharge equipment with the maximum charge current specified by the manufacturer. The charging shall be terminated when the REESS overcharge protection control terminates the REESS charge current. Where overcharge protection control of the REESS fails to operate, or if there is no such control, the charging shall be continued until the REESS temperature reaches 10 °C above its maximum operating temperature specified by the manufacturer. In the case where charge current is not terminated and where the REESS temperature remains less than 10 °C above the maximum operating temperature, the charging shall be terminated 12 hours after the start of charging by external electricity supply equipment;

(c) Immediately after the termination of charging, one standard cycle as described in Annex 9, Appendix 1 shall be conducted, if it is not prohibited by the REESS, with external charge-discharge equipment.

3.3. The test shall end with an observation period of 1 hour at the ambient temperature conditions of the test environment.

ANNEX 9H

Over-discharge protection

1. Purpose

The purpose of this test is to verify the performance of the over-discharge protection to prevent the REESS from any severe events caused by a too low SOC.

2. Installations

This test shall be conducted, under standard operating conditions, either with a complete vehicle or with the complete REESS. Ancillary systems that do not influence the test results may be omitted from the Tested-Device.

The test may be performed with a modified Tested-Device provided these modifications shall not influence the test results.

3. Procedures

3.1. General test conditions

The following requirements and condition shall apply to the test:

(a) The test shall be conducted at an ambient temperature of 20 ± 10 °C or at higher temperature if requested by the manufacturer;

(b) The SOC of REESS shall be adjusted at the low level, but within normal operating range, by normal operation recommended by the manufacturer, such as driving the vehicle or using an external charger. Accurate adjustment is not required as long as the normal operation of the REESS is enabled;

(c) For vehicle-based test of vehicles with on-board energy conversion systems (e.g. internal combustion engine, fuel cell, etc.), reduce the electrical energy from such on-board energy conversion systems, for example by adjusting the fuel level to nearly empty but enough so that the vehicle can enter into active driving possible mode;

(d) At the beginning of the test, all protection devices which would affect the function of the Tested-Device and which are relevant for the outcome of the test shall be operational.

3.2. Discharging

The procedure for discharging the REESS for vehicle-based test shall be in accordance with paragraphs 3.2.1. and 3.2.2. Alternatively, the procedure for discharging the REESS for vehicle-based test shall be in accordance with paragraph 3.2.3. For the component-based test, the discharging procedure shall be in accordance with paragraph 3.2.4.

3.2.1. Discharge by vehicle driving operation.

This procedure is applicable to the vehicle-based tests in active driving possible mode:

(a) The vehicle shall be driven on a chassis dynamometer. The vehicle operation on a chassis dynamometer (e.g. simulation of continuous driving at steady speed) that will deliver as constant discharging power as reasonably achievable shall be determined, if necessary, through consultation with the manufacturer;

(b) The REESS shall be discharged by the vehicle operation on a chassis dynamometer in accordance with paragraph 3.2.1.(a). The vehicle operation on the chassis dynamometer shall be terminated when the vehicle's over-discharge protection control terminates REESS discharge current or the temperature of the REESS is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours. Where an over-discharge protection control fails to operate, or if there is no such control, then the discharging shall be continued until the REESS is discharged to 25 per cent of its nominal voltage level;

(c) Immediately after the termination of discharging, one standard charge followed by a standard discharge as described in Annex 9, Appendix 1 shall be conducted if it is not prohibited by the vehicle.

3.2.2. Discharge by auxiliary electrical equipment (vehicle-based test).

This procedure is applicable to the vehicle-based tests in stationary condition:

(a) The vehicle shall be switched in to a stationary operation mode that allow consumption of electrical energy from REESS by auxiliary electrical equipment. Such an operation mode shall be determined, if necessary, through consultation with the manufacturer. Equipment (e.g. wheel chocks) that prevent the vehicle movement may be used as appropriate to ensure the safety during the test;

(b) The REESS shall be discharged by the operation of electrical equipment, air-conditioning, heating, lighting, audio-visual equipment, etc., that can be switched on under the conditions given in paragraph 3.2.2.(a). The operation shall be terminated when the vehicle's over-discharge protection control terminates REESS discharge current or the temperature of the REESS is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours. Where an over-discharge protection control fails to operate, or if there is no such control, then the discharging shall be continued until the REESS is discharged to 25 per cent of its nominal voltage level;

(c) Immediately after the termination of discharging, one standard charge followed by a standard discharge as described in Annex 9, Appendix 1 shall be conducted if it is not prohibited by the vehicle.

3.2.3. Discharge of REESS using discharge resistor (vehicle-based test).

This procedure is applicable to vehicles for which the manufacturer provides information to connect a breakout harness to a location just outside the REESS that permits discharging the REESS:

(a) Connect the breakout harness to the vehicle as specified by the manufacturer. Place the vehicle in active driving possible mode;

(b) A discharge resistor is connected to the breakout harness and the REESS shall be discharged at a discharge rate under normal operating conditions in accordance with manufacturer provided information. A resistor with discharge power of 1 kW may be used;

(c) The test shall be terminated when the vehicle's over-discharge protection control terminates REESS discharge current or the temperature of the REESS is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours. Where an automatic discharge interrupt function fails to operate, or if there is no such function, then the discharging shall be continued until the REESS is discharged to 25 per cent of its nominal voltage level;

(d) Immediately after the termination of discharging, one standard charge followed by a standard discharge as described in Annex 9, Appendix 1 shall be conducted if it is not prohibited by the vehicle.

3.2.4. Discharge by external equipment (component-based test).

This procedure is applicable to component-based test:

(a) All relevant main contactors shall be closed. The external charge-discharge shall be connected to the main terminals of the Tested-Device;

(b) A discharge shall be performed with a stable current within the normal operating range as specified by the manufacturer;

(c) The discharging shall be continued until the Tested-Device (automatically) terminates REESS discharge current or the temperature of the Tested-Device is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours. Where an automatic interrupt function fails to operate, or if there is no such function, then the discharging shall be continued until the Tested-Device is discharged to 25 per cent of its nominal voltage level;

(d) Immediately after the termination of the discharging, one standard charge followed by a standard discharge as described in Annex 9, Appendix 1 shall be conducted if not inhibited by the Tested-Device.

3.3. The test shall end with an observation period of 1 h at the ambient temperature conditions of the test environment.

ANNEX 9I

Over-temperature protection

1. Purpose

The purpose of this test is to verify the performance of the protection measures of the REESS against internal overheating during the operation. In the case that no specific protection measures are necessary to prevent the REESS from reaching an unsafe state due to internal over-temperature, this safe operation must be demonstrated.

2. The test may be conducted with a complete REESS according to paragraphs 3. and 4. or with a complete vehicle according to paragraphs 5. and 6.

3. Installation for test conducted using a complete REESS

3.1. Ancillary systems that do not influence to the test results may be omitted from the Tested-Device. The test may be performed with a modified Tested-Device provided these modifications shall not influence the test results.

3.2. Where a REESS is fitted with a cooling function and where the REESS will remain functional in delivering its normal power without a cooling function system being operational, the cooling system shall be deactivated for the test.

3.3. The temperature of the Tested-Device shall be continuously measured inside the casing in the proximity of the cells during the test in order to monitor the changes of the temperature. The on-board sensor, if existing may be used with compatible tools to read the signal.

3.4. The REESS shall be placed in a convective oven or climatic chamber. If necessary, for conducting the test, the REESS shall be connected to the rest of vehicle control system with extended cables. An external charge/discharge equipment may be connected under supervision by the vehicle manufacturer.

4. Test procedures for test conducted using a complete REESS.

4.1. At the beginning of the test, all protection devices which affect the function of the Tested-Device and are relevant to the outcome of the test shall be operational, except for any system deactivation implemented in accordance with paragraph 3.2. above.

4.2. The Tested-Device shall be continuously charged and discharged by the external charge/discharge equipment with a current that will increase the temperature of cells as rapidly as possible within the range of normal operation as defined by the manufacturer until the end of the test.

Alternatively, the charge and discharge may be conducted by vehicle driving operations on chassis dynamometer where the driving operation shall be determined through consultation with the manufacturer to achieve the conditions above.

4.3. The temperature of the chamber or oven shall be gradually increased, from 20 ± 10 °C or at higher temperature if requested by the manufacturer, until it reaches the temperature determined in accordance with paragraph 4.3.1. or 4.3.2. below as applicable, and then maintained at a temperature that is equal to or higher than this, until the end of the test.

4.3.1. Where the REESS is equipped with protective measures against internal overheating, the temperature shall be increased to the temperature defined by the manufacturer as being the operational temperature threshold for such protective measures, to ensure that the temperature of the Tested-Device will increase as specified in paragraph 4.2. above.

4.3.2. Where the REESS is not equipped with any specific measures against internal over-heating, the temperature shall be increased to the maximum operational temperature specified by the manufacturer.

4.4. The end of test: The test will end when one of the followings is observed:

(a) The Tested-Device inhibits and/or limits the charge and/or discharge to prevent the temperature increase;

(b) The temperature of the Tested-Device is stabilised, which means that the temperature varies by a gradient of less than 4 °C through 2 hours;

(c) Any failure of the acceptance criteria prescribed in paragraph 6.9.2.1. of the Regulation.

5. Installation for test conducted using a complete vehicle.

5.1. Based on information from the manufacturer, for a REESS fitted with a cooling function the cooling system shall be disabled or in a state of significantly reduced operation (for a REESS that will not operate if the cooling system is disabled) for the test.

5.2. The temperature of the REESS shall be continuously measured inside the casing in the proximity of the cells during the test to monitor the changes of temperature using on-board sensors and compatible tools according to manufacturer provided information for reading the signals.

5.3. The vehicle shall be placed in a climate control chamber set to a temperature between 40 °C to 45 °C for at least 6 hours.

6. Test procedures for test conducted using a complete vehicle.

6.1. The vehicle shall be continuously charged and discharged in a manner that will increases the temperature of REESS cells as rapidly as possible within the range of normal operation as defined by the manufacturer until the end of the test.

The charge and discharge will be conducted by vehicle driving operations on chassis dynamometer where the driving operation shall be determined through consultation with the manufacturer to achieve the conditions above.

For a vehicle that can be charged by an external power supply, the charging may be conducted using an external power supply if more rapid temperature increase is expected.

6.2. The test will end when one of the followings is observed:

(a) The vehicle terminates the charge and/or discharge;

(b) The temperature of the REESS is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours;

(c) Any failure of the acceptance criteria prescribed in paragraph 6.9.2.1. of the Regulation;

(d) Three hours elapse from the time of starting the charge/discharge cycles in paragraph 6.1.

ANNEX 9J

Over-current protection

1. Purpose

The purpose of this test is to verify the performance of the overcurrent protection during DC external charging to prevent the REESS from any severe events caused by excessive levels of charge current as specified by the manufacturer.

2. Test conditions:

(a) The test shall be conducted at an ambient temperature of 20 ± 10 °C;

(b) The SOC of REESS shall be adjusted around the middle of normal operating range by normal operation recommended by the manufacturer such as driving the vehicle or using an external charger. The accurate adjustment is not required as long as the normal operation of the REESS is enabled;

(c) The overcurrent level (assuming failure of external DC electricity supply equipment) and maximum voltage (within normal range) that can be applied shall be determined, if necessary, through consultation with the manufacturer.

3. The overcurrent test shall be conducted in accordance with paragraph 4. or paragraph 5., as applicable and in accordance with manufacturer information.

4. Overcurrent during charging by external electricity supply.

This test procedure is applicable to vehicle-based test for vehicles that have the capability of charging by DC external electricity supply:

(a) The DC charging vehicle inlet shall be used for connecting the external DC electricity supply equipment. The charge control communication of the external electricity supply equipment is altered or disabled to allow the overcurrent level determined through consultation with the manufacturer;

(b) Charging of the REESS by the external DC electricity supply equipment shall be initiated to achieve the highest normal charge current specified by the manufacturer. The charge current is then increased over 5 seconds from the highest normal charge current to the overcurrent level determined in accordance with paragraph 2.(c) above. Charging is then continued at this overcurrent level;

(c) The charging shall be terminated when the functionality of the vehicle's overcurrent protection terminates the REESS charge current or the temperature of the REESS is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours;

(d) Immediately after the termination of charging, one standard cycle as described in Annex 9, Appendix 1 shall be conducted, if it is not prohibited by the vehicle.

5. Overcurrent during charging using breakout harness.

This test procedure is applicable to REESS for vehicles that have the capability of charging by DC external electricity supply and for which the manufacturer provides information to connect a breakout harness to a location just outside the REESS that permits charging of the REESS:

(a) The breakout harness is connected to the vehicle or REESS as specified by the manufacturer;

(b) The external electricity supply equipment along with the overcurrent supply is connected to the breakout harness and charging of the REESS is initiated to achieve the highest normal charge current specified by the manufacturer;

(c) The charge current is then increased over 5 seconds from the highest normal charge current to the overcurrent level determined in accordance with paragraph 2.(c) above. Charging is then continued at this overcurrent level;

(d) The charging shall be terminated when the functionality of the vehicle's overcurrent protection terminates charging or the temperature of the Tested-Device is stabilized such that the temperature varies by a gradient of less than 4 °C through 2 hours;

(e) Immediately after the termination of charging, one standard cycle as described in Annex 9, Appendix 1 shall be conducted, if it is not prohibited by the vehicle.

6. The test shall end with an observation period of 1 hour at the ambient temperature conditions of the test environment.

ANNEX 9K

Thermal propagation test

1. Purpose

The purpose of the thermal propagation test is to ensure occupant safety in a vehicle when a forced thermal runaway of a cell in the REESS is triggered/initiated. The phenomena of forced thermal runaway simulate a severe thermal event caused by an internal short circuit.

2. Installations

This test shall be conducted either with a complete vehicle or using the complete REESS or REESS subsystem(s) at the discretion of the manufacturer in agreement with the Technical Service. If the manufacturer chooses to test with REESS subsystem(s), the manufacturer shall demonstrate that the test result can reasonably represent the performance of the complete REESS with respect to its safety performance under the same conditions.

For a test using REESS or REESS subsystem, the parts of the vehicle relevant for the test shall be installed to the Tested-Device, in case phenomena rendering the test non-representative of REESS installed in a vehicle are expected.

3. General test conditions

The following conditions shall apply to the test.

3.1. Environmental conditions

(a) The test shall be conducted either indoors or outdoors. In case of outdoor testing there shall be no direct exposure of the vehicle/Tested-Device to precipitation for the duration of the test.

(b) Immediately before the test, the wind speed shall be measured at a location which is no more than 5 m from the Tested-Device and the average wind speed over 10 min shall be less than 7.8 m/s. It shall be ensured that the results are not affected by gusts of wind. Gusts shall not exceed 10 m/s when measured over a period of 20 s. The test set-up shall consider the impact of features such as shielding screens or walls which may create excessive funnelling effects during the test.

3.2. Tested-Device

(a) Required modifications shall be kept to a minimum compared to the original unmodified Tested-Device. Any modifications of REESS components, such as mechanical and thermal barriers, cooling plates/channels, electrical connections, and cell-to-cell spacing shall be documented and justification provided as to why such changes will not result in a significant change in performance. Confirm that the original sealing capability of the REESS is not compromised by instrumentation and that any venting shall be through pre-existing seals. All components and features that are required for the functioning of the Tested-Device and safety related features e.g. cell connecting busbars, tab welding, connection and functionality of the relevant management system, isolation resistance, etc., shall be maintained and not compromised;

(b) For the vehicle-level test, all windows, roof and doors are closed;

(c) At the beginning of the test, the State of Charge (SoC) shall be adjusted according to the procedure described in Annex 9 - Appendix 1 of this Regulation;

(d) At the beginning of the test, and for as long as possible during the test, all necessary functions of the Tested-Device shall be operational. The Tested-Device shall be representative of the REESS when installed in a vehicle that is stationary and in active-driving possible mode. The defined thermal management/safety strategy and the battery management system used in the REESS shall be fully operational. The coolant flow may be zero or active depending on the management system of the Tested-Device. The native thermal management strategy (if installed), and other relevant management systems of the Tested-Device, which are necessary for the test, shall be operational for as long as possible during the test.

(e) Immediately before turning on the initiation device, the temperature of the cells in the Tested-Device, shall be maintained between 18 °C and maximum operating temperature defined by the manufacturer.

3.3. Initiation cell

In the field, a single cell thermal runaway may occur in any REESS cell location. For the test, the selection of the initiation cell shall consider the number of adjacent cells, cell packaging, and the distance between cells in proximity to the potential initiation cell, as well as the practicality of initiation.

The intent is to allow for the selection of any cell in the pack. However, it is understood that there are differing limitations in the ability to access certain cells in any given Tested-Device and that certain cells may pose a higher risk of propagation stemming from a single cell failure. The criteria below will ensure that Tested-Device functionality and safety systems are not compromised by installation of test equipment. It also provides the basis for selecting a cell that is potentially at a higher risk of causing propagation.

Paragraph 3.3.1. below is essential to ensure that the whole system is tested and any that safety systems installed in the Tested-Device are not compromised.

Paragraph 3.3.2. below is subjective to the specific product as well as to the test level and the initiation method selected in accordance with paragraph 6.15.3. A representative case shall be determined by the Technical Service, in consultation with the manufacturer, on the basis of documentation provided by the manufacturer.

3.3.1. The installation of test equipment shall not compromise the functionality of the REESS relevant to the safety performance. The installation shall minimize modification to thermal insulators and structure and shall not:

(a) Disable or affect the functionality of the battery management systems;

(b) Change pack gas flow direction and permeability, both internal and exit paths.

3.3.2. The selected cell shall represent severe conditions for the generation of potentially hazardous conditions in the event of a thermal runaway, i.e.:

(a) A high level of heat transfer to at least one adjacent cell (e.g. thinnest spacers/gaps/barriers or vent direction towards an adjacent cell);

(b) Subject to heat sink(s) and non-productive thermal pathway(s) (e.g. edge cell with few adjacent cells and/or with large adjacent air space(s)); or

(c) Any other criteria of condition or location known by the manufacturer which could potentially to lead to a hazardous condition.

4. Recorded data and measurements

4.1. The following information shall be recorded during the test and during the observation period. All data measurement systems shall be referenced to the same starting time.

(a) Identification of the test method, including the trigger method, and a description of the test set-up;

(b) Test conditions (e.g. environmental conditions, SoC, and other pre-conditioning parameters);

(c) Temperature of the initiation cell, ensuring that the trigger device or test instrumentation does not influence the measurement;

(d) Voltage of the initiation cell during the thermal runaway triggering procedure;

(e) Temperature of one adjacent cell;

(f) Video and audio recording, including indication of a time stamp of observable events during the test (e.g. initiation cell thermal runaway and venting, thermal propagation to adjacent cell(s), smoke, fire or flame, explosion, etc.);

(g) Condition of the Tested-Device at the end of the test, supported by video or photographs (before and after test);

(h) If the test is performed on vehicle level, the time stamp of warning indications or alarms to occupants. If the test is performed on REESS or REESS subsystem, the time stamp of the signal to trigger the warning indications;

(i) The Technical Services may perform additional optional measurements and record the data, e.g. infrared temperature video, if deemed necessary.

5 Detection criteria of thermal runaway

Thermal runaway can be detected by the following conditions:

(i) The measured voltage of the initiation cell drops, and the drop value exceeds 25 per cent of the initial voltage for at least 1 second;

(ii) The measured temperature of the initiation cell exceeds the maximum operating temperature defined by the manufacturer;

(iii) $dT/dt \geq 1$ °C/s of the measured temperature of the initiation cell for at least 3 consecutive seconds.

(a) Both (i) and (iii) are detected; or

(b) Both (ii) and (iii) are detected.

6. Trigger methods to initiate thermal runaway

The trigger method shall not affect the adjacent cell(s), e.g. if localized rapid external heating, localized internal heating or laser-based trigger methods are used, the temperature of the adjacent cell(s) shall not exceed maximum operating temperature, defined by the manufacturer before the thermal runaway of the initiation cell is detected. Appropriate methods may be used to isolate the adjacent cell(s), provided that original functionality of REESS is not impeded.

Annex 9K – Appendix 1

Thermal runaway trigger method with localized fast external heater

1. Preparation of the Tested-Device

1.1. The feed-through installation of the selected heating element and measuring sensors should only modify the REESS by allowing the necessary electrical and thermocouple connections. These connections must provide greater sealing integrity than the other REESS connectors.

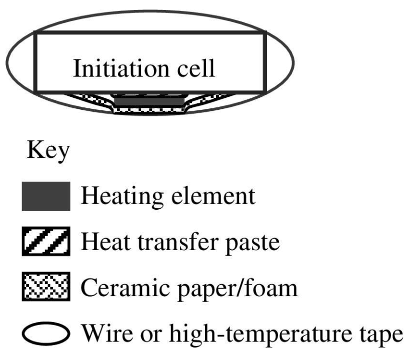
1.2. The selected heating element shall not be in direct contact with any surface of the components in the Tested-Device other than the initiation cell. Close thermal contact between the heating element and the surface of the initiation cell is important for the success of this method. Thermal contact between the heating element and initiation cell may be improved through various methods (e.g. avoid air gaps, add a heat transfer paste and apply pressure, which should be maintained throughout the test).

1.3. Examples of potential heater application methods are shown in Figure 1: the method used depends on the design of the REESS or REESS subsystem. Maintain a contact pressure for the heating element on the initiation cell during the test to ensure contact and optimal heat transfer, see Figure 1.

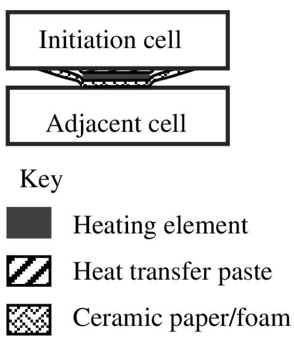
Figure 1

Methods of applying pressure on the heating element to maintain heating element contact with the initiation cell throughout the test for different cell types

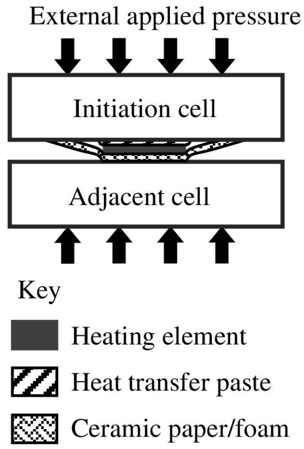
(a) REESS with large spaces between the cells



(b) Centre cell fixed spacing (e.g. prismatic cells)



(c) Centre cell compressed modules (e.g. pouch cells)

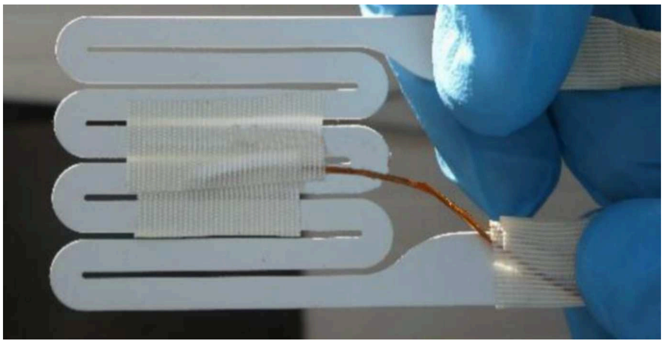


1.5. For vehicle-based tests, the vehicle response shall not be influenced by this trigger method in the REESS.

1.6. A temperature sensor shall be placed on the surface of the heating element and affixed with high-temperature resistant and electrically insulating tape for power regulation of the heater.

Figure 2

Example of placement of the temperature sensor on the heater element



2. Selection guide for the heater element

2.1. The trigger method applies a high-powered heat pulse, locally, to the external surface of the initiation cell. The successful implementation of the method requires the application of sufficient power to the chosen heating element but it shall also not apply so much power that there is a premature heating element failure nor a side wall failure of the initiation cell prior to thermal runaway.

2.2. The heating device shall be a resistive heating element, or other suitable heating device/technology capable of delivering the target parameters. See Table 1 for the target parameters for the heating element.

Table 1

Heater device selection guide: target parameters

Parameter	Value	Rationale
Heater device material	A suitable resistive heating material, e.g. nickel-chrome, with an isolating barrier	Achieve high temperatures and prevent element failures. Isolating materials may include alumina, ceramic, or fibreglass.
Thickness	< 5 mm	Minimize effect of heater on REESS. Some REESS designs may require a thinner heating element.
Area	As small as possible, but no larger than 20 per cent of the surface area of the targeted face of the initiation cell	Concentrate heat on the smallest feasible area of the cell surface. Largest cell surface should be used, if possible
Heating rate	≥ 15 °C/s	Similar to heating rates observed within thermal runaway conditions. ([a])
Maximum temperature	At least 100 °C larger than the maximum operating temperature	Heater shall maintain integrity and take into account temperature deviations from heater element to thermocouple. ([b])
Control method	Thermostatic closed loop	Avoids undesirable test results, such as heating element burnout, elevated heating element temperature, battery cell sidewall ruptures due to high element temperatures. ([c])

([a]) The heating rate is measured directly by an external thermocouple placed on top of the heating element installed in the pack (Figure 2).

([b]) This temperature may be adjusted for other chemistries and potentially other cell types to avoid cell sidewall ruptures.

([c]) Use of a low voltage power source for the heating element will require higher currents (thicker wires), while a higher voltage source will require more resistant isolating material and higher levels of user safety during the test.

3. Test procedure for vehicle-based test

The general conditions in Annex 9K, paragraph 3 shall be satisfied when the method is implemented with the vehicle.

(a) Instrument the REESS and the vehicle as outlined above and place the vehicle in the active-driving possible mode. Make sure that the cooling and communication system operate as intended.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Begin sending power to the heating element.

(d) Switch off the heater after a total energy input to the heater reaches 20 per cent of initiation cell energy.

(e) If (d) is satisfied, but thermal runaway has not occurred in the initiation cell during the observation period of 1 hour after the opening of the heater relay, the REESS type is considered to comply with this requirement.

(f) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with subparagraph (d) above followed by an observation period of 1 hour; or

(ii) At least 5 minutes elapse after the activation of the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

4. Test procedure for component-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented on the REESS or REESS subsystem.

(a) Instrument the REESS or REESS subsystem as outlined above and prepare the REESS or REESS subsystem such that it represents the situation when it is installed in the vehicle, with the system in the active-driving possible mode. Make sure that the thermal management and communication system operate as intended.

(b) Start recording the necessary data to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Begin sending power to the heating element.

(d) Switch off the heater immediately when thermal runaway is confirmed or after total energy input to the heater reaches 20 per cent of initiation cell electric energy.

(e) If (d) is satisfied, but thermal runaway has not occurred in the initiation cell during the observation period of 1 hour after the opening of the heater relay, the REESS type is considered to comply with this requirement.

(f) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (d) above followed by an observation period of 1 hour; or

(ii) at least 5 minutes elapse after the signal to activate the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

Annex 9K – Appendix 2

Thermal runaway trigger method with internal heater

This test method is similar to the localised fast external heating method except it relies on an internal, localized short circuit inside the cell created by a heater. The concept of this trigger method is to create an internal short circuit by creating a hole in the separator of the initiation cell. The hole comes from the local melting of the separator induced by the local heater.

The trigger method applies a high-power heat pulse, locally, to the jellyroll surface of one initiation cell within the REESS via an internal heater with minimal increase in temperature of the adjacent battery cell(s) prior to thermal runaway in the initiation cell. The temperature of adjacent cell(s), prior to thermal runaway in the initiation cell, shall remain below the maximum operating temperature.

1. Description of the trigger method

The heating device shall be a resistive heating element, or other suitable heating device/technology capable of delivering the target parameters. Target parameters for the heating element are listed in Table 1.

The resistance, power and duration shall be adjusted according to the electrochemistry and the size of the cell.

Figure 1

Example of an internal heater flat spiral

(Dimensions in millimetres)

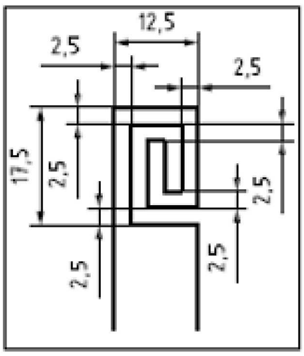


Table 1

Heating element selection guide: target parameters

Parameter	Value	Reasoning
Heating element material	A suitable resistive heating material with an insulating barrier, e.g. copper or tungsten	Achieve high temperatures and prevent element failures. Isolating material may include polyimide or other heat-resisting material.
Thickness (mm)	≤ 0.5	As the heater needs to be placed inside of a cell, thickness of heater should be minimized.

Parameter	Value	Reasoning
Area (mm²)	225 - 500	Concentrate heat to the smallest feasible area on the jellyroll surface.
Power of heater (W)	150~700	Provide enough heat to enable initiation of cell thermal runaway.

2. Initiation cell/cell block preparation

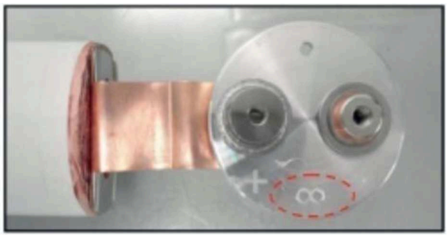
The heater shall be inserted in the connected electrode stack or jellyroll before cell sealing. The applied method is dependent on the REESS or REESS subsystem design and manufacturing process. Here is an example of the manufacturing process for this special cell.

2.1. Step 1:

One or two hole(s) are drilled into the cover to allow the electrical feedthrough of the heater from inside the cell to the outside (Figure 2).

Figure 2

Example of specific holes in cover for heater connection



2.2. Step 2:

Unroll the separators and the electrodes to insert the heater.

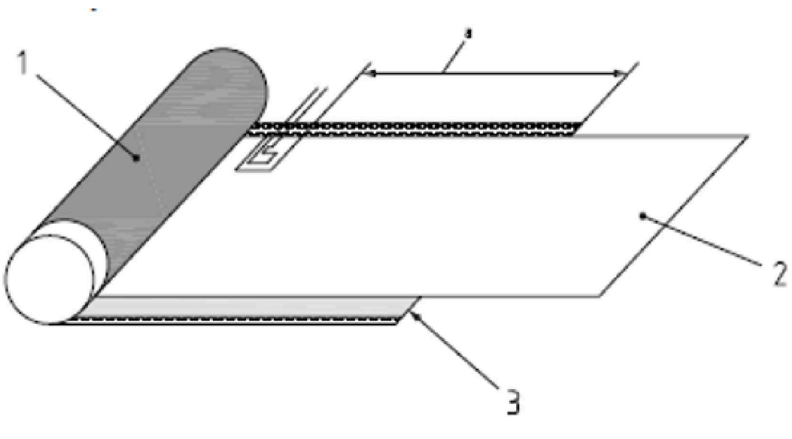
2.3. Step 3:

Locate the heater on the last wrap of electrode. The heater is placed between the outermost negative and positive electrodes for the cell (see Figures 3, 4 and 5).

Avoid unrolling a larger part of the jelly roll, since this can lead to damage of the jelly roll. Use an outer stack in case of stacked layers.

Figure 3

Example of heater location inside the cylindrical cell



Key

1 positive electrode

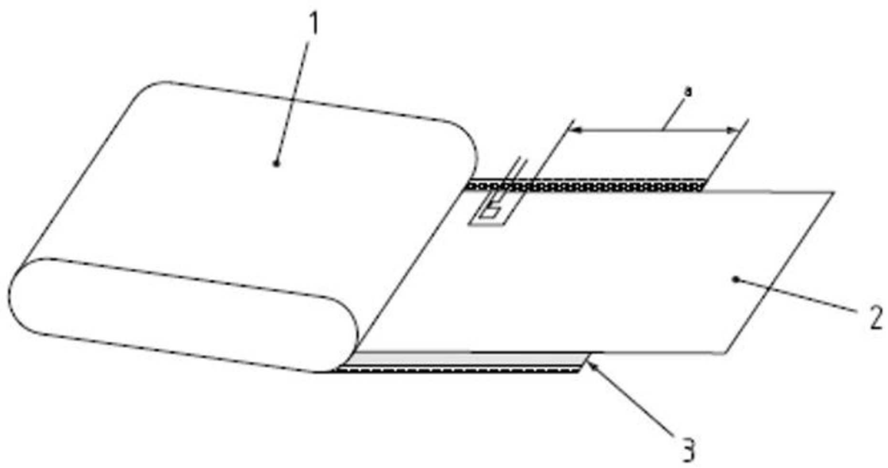
2 separator

3 negative electrode

a 180 mm from end of positive electrode and 15 mm from end of negative electrode, tolerance ±5 mm

Figure 4

Example of heater location inside the prismatic cell



Key

1 positive electrode

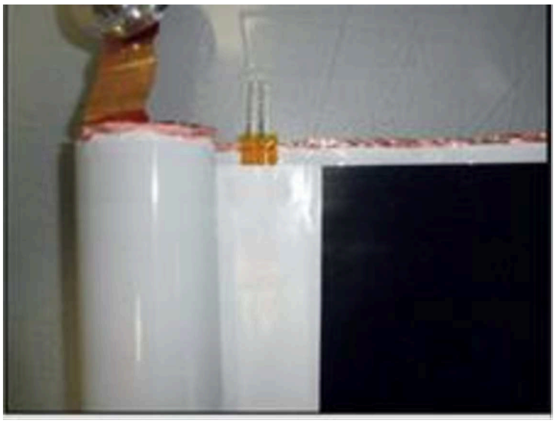
2 separator

3 negative electrode

a 180 mm from end of positive electrode and 15 mm from end of negative electrode, tolerance ±5 mm

Figure 5

Example of located on the last lap of negative electrode

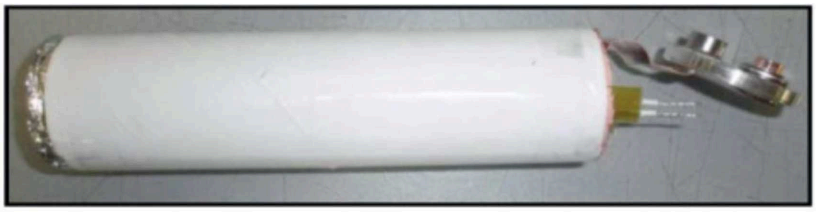


2.4. Step 4:

Wind the jelly roll with the heater (see Figure 6).

Figure 6

Example of jelly roll equipped with heater



2.5. Step 5:

All wires used in the REESS or REESS subsystem shall be electrically isolated.

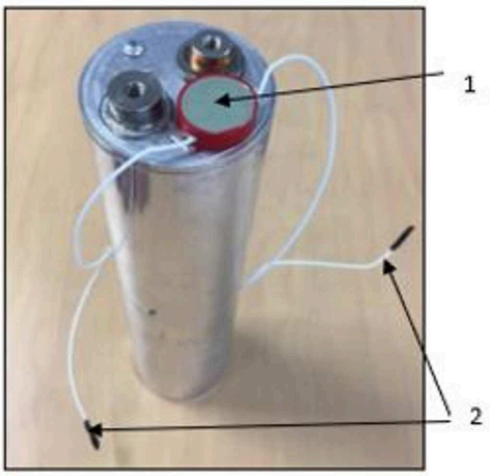
The cell shall be assembled according to standard manufacturing processes (e.g. electrolyte filling, cover welding), ensuring no electrolyte or gases can leak out through the space between the wire strand and the wire insulator.

Selection of resin is critical as the strength of seal shall be greater than any installed vent of the cell.

After the resin is completely dry, carry out a helium test to check the sealing before filling the cell with electrolyte.

Figure 7

Example of finished cell with heater



Key

1 resin for sealing the heater supply

2 supply wires of the heater

Figure 8

Example of cell before filling with electrolyte

2.6. Step 6:

The initiation cell shall be assembled inside the REESS or REESS subsystem, which could be modified to make sure the electrical feedthrough of the heater can come out of cell block.

The feedthrough installation of the heating element and measuring sensors should only modify the REESS (or REESS subsystem) by permitting necessary electrical and thermocouple connections. These connections shall provide greater seal integrity than the other connectors in the REESS (or REESS subsystem).

For a vehicle level test, mount the REESS on the vehicle, according to manufacturer's specifications.

3. Test procedure for the vehicle-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented with the vehicle.

(a) Instrument the REESS and the vehicle as outlined above and place the vehicle in the active-driving possible mode. Make sure that the cooling and communication system operate as intended.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Begin sending power to the heating element.

(d) Switch off the heater immediately when thermal runaway is confirmed or after a total energy input to the heater reaches 20 % of initiation cell electric energy.

(e) If (d) is satisfied, but no thermal runaway has occurred in the initiation cell during the observation period of 1 hour after the opening of the heater relay, the REESS type is considered to comply with this requirement.

(f) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (d) above followed by an observation period of 1 hour; or

(ii) At least 5 minutes elapse after the activation of the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

4. Test procedure for the component-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented on the REESS or REESS subsystem.

(a) Instrument the REESS or REESS subsystem as outlined above and prepare the REESS or REESS subsystem such that it represents the situation when it is installed in the vehicle, with the system in the active-driving possible mode. Make sure that the thermal management and communication system operate as intended.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Begin sending power to the heating element.

(d) Switch off the heater immediately when thermal runaway is confirmed or after a total energy input to the heater reaches 20 % of initiation cell electric energy.

(e) If (d) is satisfied, but no thermal runaway has occurred in the initiation cell during the observation period of 1 hour after the opening of the heater relay, the REESS type is considered to comply with this requirement.

(f) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (d) above followed by an observation period of 1 hour; or

(ii) At least 5 minutes elapse after the signal to activate the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

Annex 9K – Appendix 3

Thermal runaway trigger method with nail penetration

1. Preparation of the Tested-Device

If the REESS is enclosed in a housing, a penetrating hole on the housing may be needed to enable the nail to be inserted into a target position of an initiation cell. The device such as gas tight sleeve for the nail that prevents venting gas from leaking out from the nail hole should be applied, if necessary.

The nail penetrating position and direction are selected from the position and direction of the nail where causing a thermal runaway in an initiation cell is possible (e.g. in perpendicular direction to electrode layer).

2. Nail selection guide

The nail type can be chosen from the parameters given in Table 1, or other appropriate international standards. (e.g. for the shape of the nail tip).

The details of trigger method including appropriate parameters recommended by the manufacturer in accordance with paragraph 6.15.3.1.(f) shall be respected subject to the agreement of the Technical Service.

Table 1

Nail selection guide: target parameters

Parameter		Value	Rationale
(i)	Material	Steel	To be electrically conductive and sufficiently hard to penetrate a cell outer case.
(ii)	Diameter (mm)	3 to 8	To be smaller to simulate the internal short circuit.
(iii)	Angle of tip (°)	20 to 60	To be smaller to minimize effect on the cell casing. To select angle to cause thermal runaway.
(iv)	Penetrating speed (mm/s)	0.1 to 1	If the speed is low, the nail travelling is easily controlled, especially to stop.

3. Test procedure for the vehicle-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented with the vehicle.

(a) Instrument the REESS as outlined above and connect all thermal management and high voltage lines, and reinstall REESS into vehicle.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Select the nail shape and diameter and set the appropriate penetrating speed according to the guidance in paragraph 2.(iv).

(d) Tune on the power to the nail operating device.

(e) Stop the nail and let it remain inside the initiation cell when the thermal runaway is confirmed or the nail has penetrated both the front and back side of the cell.

(f) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (e) above followed by an observation period of 1 hour; or

(ii) At least 5 minutes elapse after the activation of the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

4. Test procedure for the component-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented on the REESS or REESS subsystem.

(a) Instrument the REESS or REESS subsystem as outlined above and prepare the REESS or REESS subsystem such that it represents the situation when it is installed in the vehicle, with the system in the active-driving possible mode. Make sure that the thermal management and communication system operate as intended.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that there fault codes or failures relevant for the outcome of the test are not in the system.

(c) Select the nail shape and diameter and set the appropriate penetrating speed according to the guidance in paragraph 2.(iv).

(d) Tune on the power to the nail operating device.

(e) Stop the nail and let it remain inside the initiation cell when thermal runaway is confirmed or the nail has penetrated both the front and back side of the cell.

(f) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (e) above followed by an observation period of 1 hour; or

(ii) At least 5 minutes elapse after the signal to activate the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

Annex 9K – Appendix 4

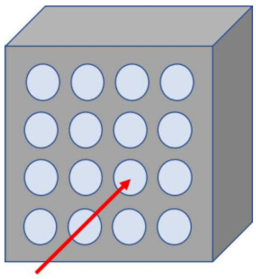
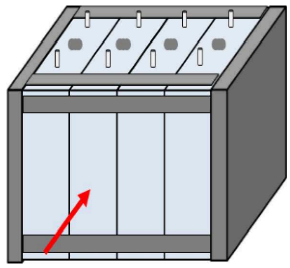
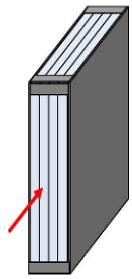
Thermal runaway trigger method with laser-based trigger

1. Preparation of the Tested-Device

Before conducting the test, the laser beam path shall be secured so that the laser beam reaches a predetermined position on the initiation cell surface. Figure 1 shows examples of laser irradiation to on-board battery modules consisting of different types of battery cells.

Figure 1

Examples of laser irradiation to on-board battery modules consisting of different types of battery cells

(a) Cylindrical cell module	(b) Square cell module	(c) Pouch cell module
		

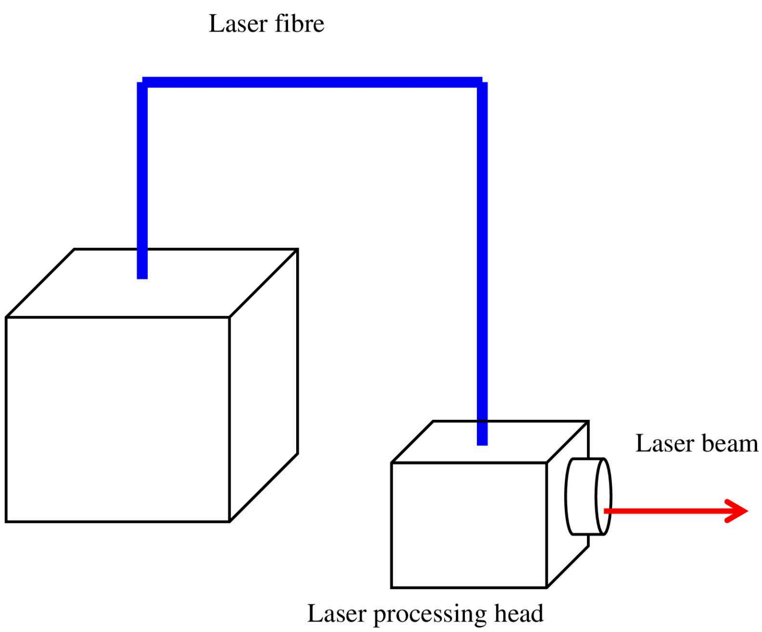
2. Laser selection guide

The laser type can be chosen from material process lasers such as used for cutting, welding or hardening, e.g. CO_2 laser, YAG laser, semiconductor laser, disk laser, fibre laser, and so on.

An example of a laser irradiation system is shown in Figure 2.

Figure 2

Example of a laser irradiation system



3. Test procedure for a vehicle-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented with the vehicle.

(a) Instrument the REESS as outlined above and connect all thermal management and high voltage lines, and reinstall REESS into vehicle.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Before starting the test, secure the laser beam path so that the laser beam reaches the initiation cell surface of the Tested-Device.

(d) Set and confirm the laser irradiation program.

(e) Irradiate the initiation cell with the laser at the determined point.

(f) Stop the laser irradiation program when thermal runaway is confirmed or after a total energy input from the laser reaches 20 per cent of the initiation cell energy.

(g) If (f) is satisfied, but no thermal runaway has occurred in the initiation cell during the observation period of 1 hour after the laser switch off, the REESS type is considered to comply with this requirement.

(h) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (f) above followed by an observation period of 1 hour; or

(ii) 5 minutes after the activation of the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but no thermal propagation ensued, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

4. Test procedure for a component-based test

The general conditions in Annex 9K, paragraph 3. shall be satisfied when the method is implemented on the REESS or REESS subsystem.

(a) Instrument the REESS or REESS subsystem as outlined above and prepare the REESS or REESS subsystem such that it represents the situation when it is installed in the vehicle, with the system in the active-driving possible mode. Make sure that the thermal management and communication system operate as intended.

(b) Start recording the data that are needed to determine if thermal runaway and/or thermal propagation occur. Verify that fault codes or failures relevant for the outcome of the test are not in the system.

(c) Before starting the test, secure the laser beam path so that the laser beam reaches the initiation cell surface of the Tested-Device.

(d) Set and confirm the laser irradiation program.

(e) Irradiate the initiation cell with the laser at the determined point.

(f) Stop the laser irradiation program when thermal runaway is confirmed or after a total energy input from the laser reaches 20 per cent of the initiation cell energy.

(g) If (f) is satisfied, but thermal runaway has not occurred in the initiation cell during the observation period of 1 hour after the laser switch off, the REESS type is considered to comply with this requirement.

(h) The test ends when one of the conditions specified below is met:

(i) The initiation is stopped in accordance with the subparagraph (f) above followed by an observation period of 1 hour; or

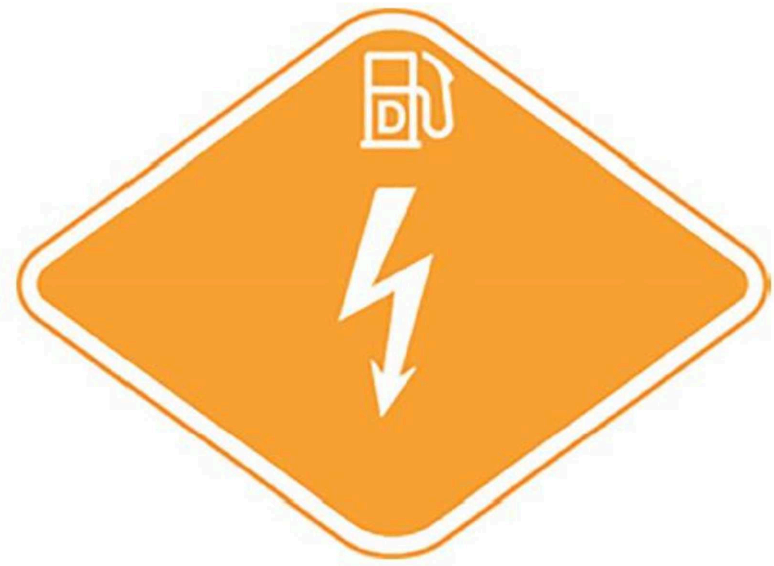
(ii) 5 minutes after the signal to activate the warning indication, if thermal propagation is observed; or

(iii) If thermal runaway has occurred in the initiation cell, but thermal propagation did not ensue, the observation period of 2 hours after the confirmation of thermal runaway is applied to Tested-Device.

ANNEX 10

Provisions for a label for vehicles of categories M_2/N_2 and M_3/N_3 equipped with an electric power train

(Paragraph 5.5.1 to 5.5.3. of this Regulation)



The label shall be weather resistant.

The centre zone indicates the first energy source.

The upper zone indicates the second energy source.

Layout and symbols shall be in accordance with ISO 17840-4:2018.

The colour and dimensions of the label shall fulfil the following requirements:

Colours:

Background:	Orange, RGB code 255, 165, 0
Border:	white reflecting
Letters:	white reflecting

Dimensions:

Sticker width:	≥ 110 mm
Sticker height:	≥ 80 mm