ANNEX IV
Requirements regarding electrical safety

1. Requirements for the approval of a type of vehicle with regard to electrical safety

1.1. Vehicles which are propelled by means of one or more electric motors, including pure and hybrid electric vehicles, shall fulfil the requirements of this Annex.

2. General requirements concerning the protection against electrical shock and electrical safety applying to high voltage buses under conditions where they are not connected to external high voltage power supplies.

2.1. The protection against direct contact with live parts shall comply with the requirements set out below. The protections provided (e.g. solid insulator, barrier, enclosure) shall not be able of being opened, disassembled or removed without the use of tools.

The protection against access to live parts shall be tested in accordance with the provisions laid down in Appendix 3 – Protection against direct contacts of parts under voltage.

2.1.1. For protection of live parts inside the enclosed driving and passenger compartment as well as luggage compartment the protection degree IPXXD shall be met.

2.1.2. For protection of live parts in areas other than the enclosed driving and passenger compartment or luggage compartment, the protection degree IPXXB shall be met.

2.1.3. For protection of live parts of vehicles where no enclosed driving and passenger compartment is present, the protection degree IPXXD shall be met by the entire vehicle.

2.1.4. Connectors (including vehicle inlet) are deemed to meet the requirements if:

- they also comply with the protection degree IPXXB when separated without the use of tools;
- they are located underneath the vehicle floor and are provided with a locking mechanism (e.g. screw locking, bayonet locking);
- they are provided with a locking mechanism and other components shall first be removed with the use of tools in order to separate the connector; or
- the voltage of the live parts becomes ≤ DC 60 V or ≤ AC 30 V (rms) within one second after the connector is separated.

2.1.5. In case a service disconnect can be opened, disassembled or removed without the use of tools, the protection degree IPXXB shall be met under all these conditions.

2.1.6. Specific marking requirements

2.1.6.1. In the case of a REESS having high voltage capability, the symbol shown in Figure 4-1 shall be placed on or near the REESS. The symbol background shall be yellow, the bordering and the arrow shall be black.

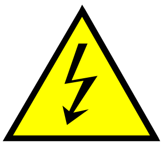


Figure 4-1

Marking of high voltage equipment

2.1.6.2. The symbol shall in addition be placed on all enclosures and barriers, which when removed expose live parts of high voltage circuits. This provision is optional for connectors for high voltage buses and does not apply to any of the following cases:

- Where barriers or enclosures cannot be physically accessed, opened, or removed unless other vehicle components are removed with the use of tools; or
- Where barriers or enclosures are located underneath the vehicle floor.

2.1.6.3. Cables for high voltage buses which are not located fully within enclosures shall be identified by having an outer covering with the colour orange.

2.2. The protection against indirect contact with live parts shall comply with the requirements set out below.

2.2.1. Concerning protection against electrical shock which could arise from indirect contact, the exposed conductive parts, such as the conductive barrier and enclosure, shall be securely galvanically connected to the electrical chassis for instance by connections with electrical wire, ground cable, welds or by connections using bolts so that no dangerous electric potential can exist.

2.2.2. 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 A. This requirement is deemed as satisfied if the galvanic connection has been established by welding.

2.2.3. In the case of vehicles intended to be connected to a grounded external electric power supply through a conductive connection, a device enabling the galvanic connection of the electrical chassis to the earth ground shall be provided.

The device shall enable connection to the earth ground before external voltage is supplied to the vehicle and shall retain this connection until after the exterior voltage is removed from the vehicle.

Compliance with these requirements may be demonstrated by using the connector specified by the vehicle manufacturer or by other analysis.

2.2.3.1. A galvanic connection of the electrical chassis to the earth ground does not need to be provided in the following cases:

- the vehicle can only use a dedicated charger that is protected when any single isolation fault arises;
- the vehicle's whole metallic body is protected when any single isolation fault arises; or
- the vehicle cannot be charged without completely removing the traction battery pack from the vehicle.

2.3. Isolation resistance shall comply with the requirements set out below.

2.3.1. Concerning electric power trains consisting of separate DC or AC-buses:

If AC buses and DC buses are galvanically isolated from each other, isolation resistance between all high voltage busses and the electrical chassis shall have a minimum value of 100 Ω/V of the working voltage for DC buses, and a minimum value of 500 Ω/V of the working voltage for AC buses.

The measurements shall be conducted in accordance with the provisions laid down in Appendix 1 – Isolation resistance measurement method.

2.3.2. Concerning 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 all high voltage busses and the electrical chassis shall have a minimum value of 500 Ω/V 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:

- double or more layers of solid insulators, barriers or enclosures that meet the requirements of points 2.1. to 2.1.6.3. independently, for example wiring harness; or
- 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 Appendix 1 – Isolation resistance measurement method.

2.3.3. Concerning Fuel cell vehicles:

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

- double or more layers of solid insulators, barriers or enclosures that meet the requirements of points 2.1. to 2.1.6.3. independently; or

– on-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value. The isolation resistance between the high voltage bus of the coupling system for charging the REESS, which is not energized besides during charging the REESS, and the electrical chassis need not be monitored.

The correct functioning of the on-board isolation resistance monitoring system shall be tested as described in Appendix 2 – Confirmation method for function of on-board isolation resistance monitoring system.

2.3.4. Isolation resistance requirements for the coupling system for charging the REESS.

The vehicle inlet or the recharge cable when permanently connected to the vehicle, intended to be conductively connected to the grounded external AC power supply and the electrical circuit that is galvanically connected to the vehicle inlet/recharge cable during charging of the REESS, shall have an isolation resistance between the high voltage bus and the electrical chassis of at least 1.0 MΩ when the charger coupler is disconnected. During the measurement, the traction battery may be disconnected.

3. Requirements concerning the REESS

3.1. Protection in case of excessive current.

The REESS shall not overheat in case of excessive current or, if the REESS is prone to overheating due to excessive current, it shall be equipped with one or more protective devices such as fuses, circuit breakers and/or main contactors.

When applicable, the vehicle manufacturer shall supply relevant data and analysis proving that overheating from excessive current is prevented without the use of protective devices.

3.2. Prevention of accumulation of gas.

Places for containing open type traction battery that may produce hydrogen gas shall be provided with a ventilation fan or a ventilation duct or any other suitable means to prevent the accumulation of hydrogen gas. Vehicles with open type framework that do not allow accumulation of hydrogen gas at such places are not required to have a ventilation fan or a ventilation duct.

3.3. Protection against electrolyte spills.

Electrolyte shall not spill from the vehicle when the vehicle is tilted in any direction, leaned left or right against the ground or even when the REESS is put upside-down.

In case electrolyte is spilled from the REESS or its components due to other reasons, it shall not reach the driver nor any person on or around the vehicle during normal conditions of use, parked condition (i.e. also when the vehicle is parked on a slope) or any other normal functional operation.

3.4. Accidental or unintentional detachment.

The REESS and its components shall be installed in the vehicle in such a way so as to preclude the possibility of inadvertent or unintentional detachment or ejection of the REESS.

The REESS and its components shall not be ejected when the vehicle is tilted in any direction, leaned left or right against the ground or even when the REESS is put upside-down

4. In-use safety requirements

4.1. Propulsion system power-on and power-off procedure

4.1.1. At the start-up, including system power-on, in order to select the active driving possible mode, at least two deliberate and distinctive actions shall be performed by the driver.

4.1.2. At least a momentary indication shall be given to the rider when the vehicle is switched in active driving possible mode, however, this provision does not apply under conditions where an internal combustion engine provides directly or indirectly the vehicle's propulsion power.

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

4.1.4. If the on-board REESS can be externally charged by the driver, vehicle movement by its own propulsion system shall be impossible as long as the connector of the external electric power supply is physically connected to the vehicle inlet. Compliance with this requirement shall be demonstrated by using the connector specified by the vehicle manufacturer.

In case of permanently connected charge cables, the requirement above is deemed to be met when use of the charge cable obviously prevents the use of the vehicle (e.g. cable is always routed over operator controls, rider's saddle, driver's seat, handle bar or steering wheel, or the seat covering the cable storage space needs to remain in open position).

4.1.5. If a vehicle is equipped with a drive direction control unit (i.e. reversing device) the state of this unit shall be identified to the rider.

4.1.6. It is permitted that only one action is required to deactivate the active driving possible mode or to complete the power-off procedure.

4.2. Driving with reduced power

4.2.1. Indication of reduced power

If the electric propulsion system is equipped with a means to automatically reduce the vehicle propulsion power (e.g. powertrain malfunction operating mode), significant reductions shall be indicated to the rider.

4.2.2. Indication of low energy content of REESS

If the state of charge in the REESS has a significant impact on vehicle driving performance (i.e. acceleration and drivability, to be evaluated by the Technical Service together with the vehicle manufacturer), a low energy content shall be indicated to the rider by an obvious device (e.g. a visual or audible signal). The indication used for point 4.2.1. shall not be used for this purpose.

4.3. Driving backwards

It shall not be possible to activate the vehicle reverse control function whilst the vehicle is in forward motion.

4.4. Determination of hydrogen emissions

4.4.1. This verification shall be carried out on all vehicle types equipped with open type traction batteries and all requirements shall be met.

4.4.2. Vehicles shall be equipped with on-board chargers. The tests shall be conducted following the method described in Annex 7 to UNECE Regulation No 100. The hydrogen sampling and analysis shall be the ones as prescribed, however, other analysis methods may be used provided that it can be demonstrated that these give equivalent results.

4.4.3. During a normal charge procedure under the conditions given in Annex 7 to UNECE Regulation No 100, hydrogen emissions shall be < 125 g measured over 5 hours, or below (25 x t_2) (g) during t_2 (h).

4.4.4. During a charge carried out by an on-board charger presenting a failure (conditions given in Annex 7 to UNECE Regulation No 100), hydrogen emissions shall be below 42 g. Furthermore the on-board charger shall limit this possible failure to 30 minutes.

4.4.5. All the operations linked to the REESS charging shall be controlled automatically, included the stop for charging.

4.4.6. It shall not be possible to manually override the charging phases.

4.4.7. Normal operations of connection and disconnection to the mains or power cuts shall not affect the control system of the charging phases.

4.4.8. Charging failures that can lead to a malfunction of the on-board charger during subsequent charging procedures shall be permanently signalled to the driver or clearly indicated to the operator about to commence a charging procedure.

4.4.9. Detailed instructions concerning the charging procedure and a statement of conformity to the requirements as set out in points 4.4.1. to 4.4.8. shall be included in the vehicle's instruction manual.

4.4.10. Test results obtained from other vehicle types common to those within the same family, in accordance with the provisions laid down in Appendix 2 of Annex 7 to Regulation No 100, may be applied.

Appendix 1 – Isolation resistance measurement method for vehicle based test

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 points 2.1. to 2.2., depending on the electrical charge of the live parts or the isolation resistance, etc.

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

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

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

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

2.1. Measurement method using voltage from off-vehicle sources

2.1.1. Measurement instrument

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

2.1.2. Measurement method

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

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

2.2. Measurement method using the vehicle's own 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 4-Ap1-1 and the high voltage bus voltage (Vb) is recorded. Vb 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.

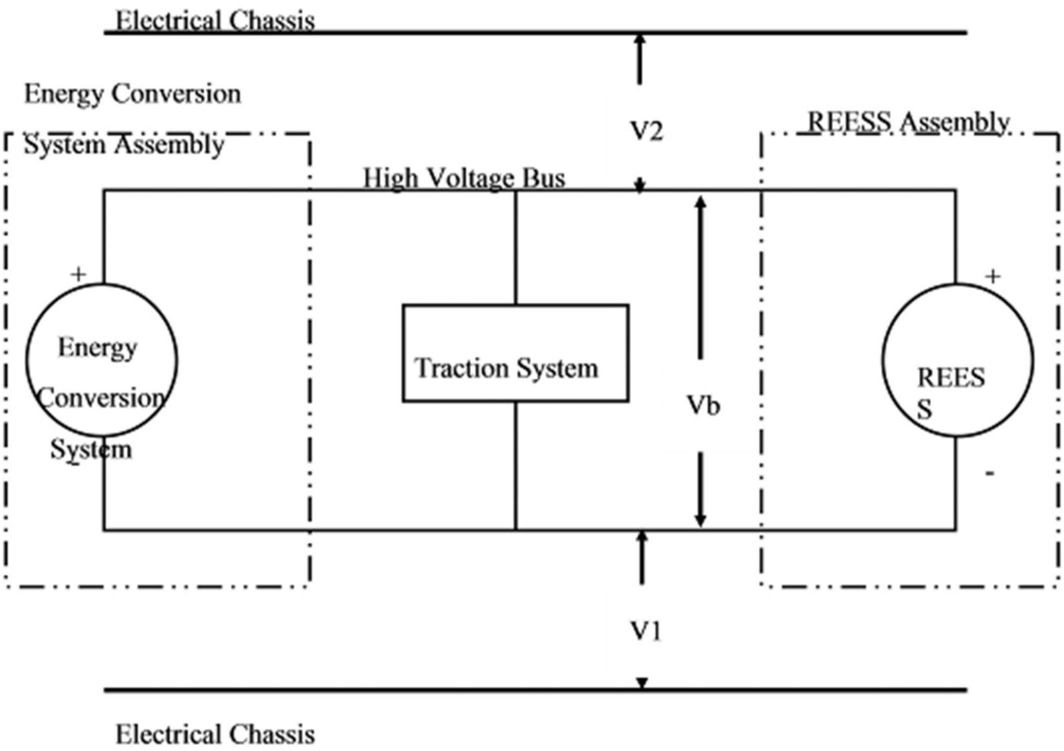


Figure 4-Ap1-1

Measurement of Vb, V1, V2

2.2.3.2. Second step

Measure and record the voltage (V1) between the negative side of the high voltage bus and the electrical chassis (see Figure 4-Ap1-1).

2.2.3.3. Third step

Measure and record the voltage (V2) between the positive side of the high voltage bus and the electrical chassis (see Figure 4-Ap1-1).

2.2.3.4. Fourth step

If V1 is greater than or equal to V2, insert a standard known resistance (Ro) between the negative side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage (V1') between the negative side of the high voltage bus and the electrical chassis (see Figure 4-Ap1-2).

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

Ri = Ro*(Vb/V1' – Vb/V1) or Ri = Ro*Vb*(1/V1' – 1/V1)

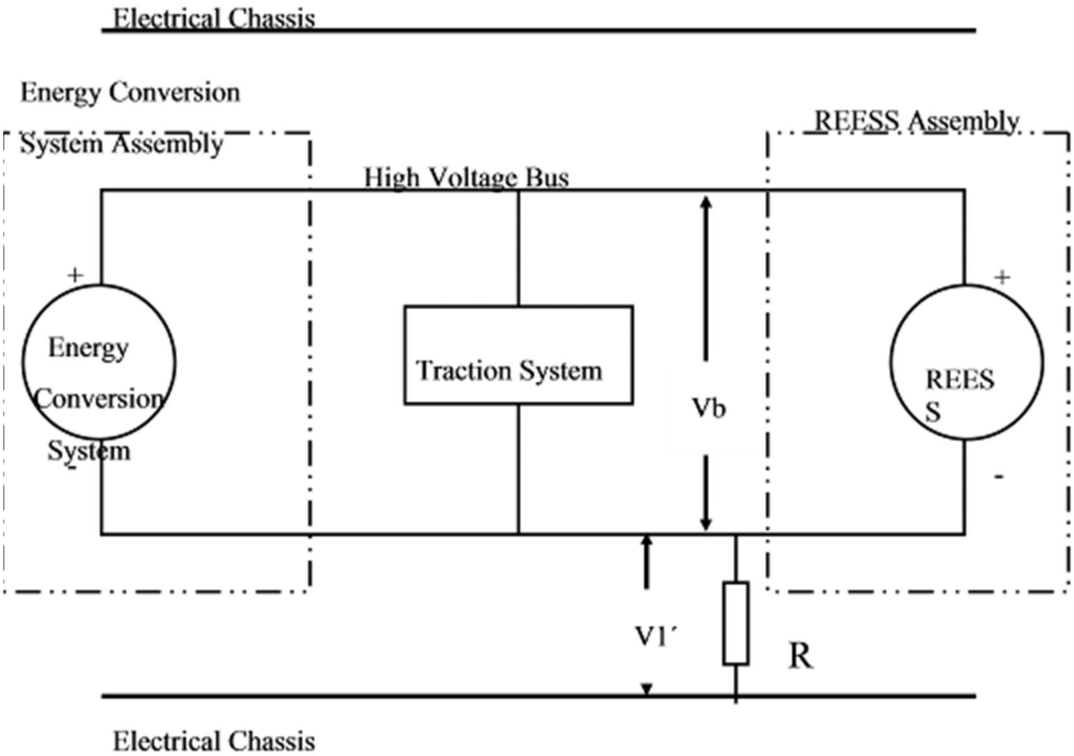


Figure 4-Ap1-2

Measurement of V1'

If V2 is greater than V1, insert a standard known resistance (Ro) between the positive side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage (V2') between the positive side of the high voltage bus and the electrical chassis (see Figure 4-Ap1-3). 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 V).

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

Ri = Ro*(Vb/V2' – Vb/V2) or Ri = Ro*Vb*(1/V2' – 1/V2)

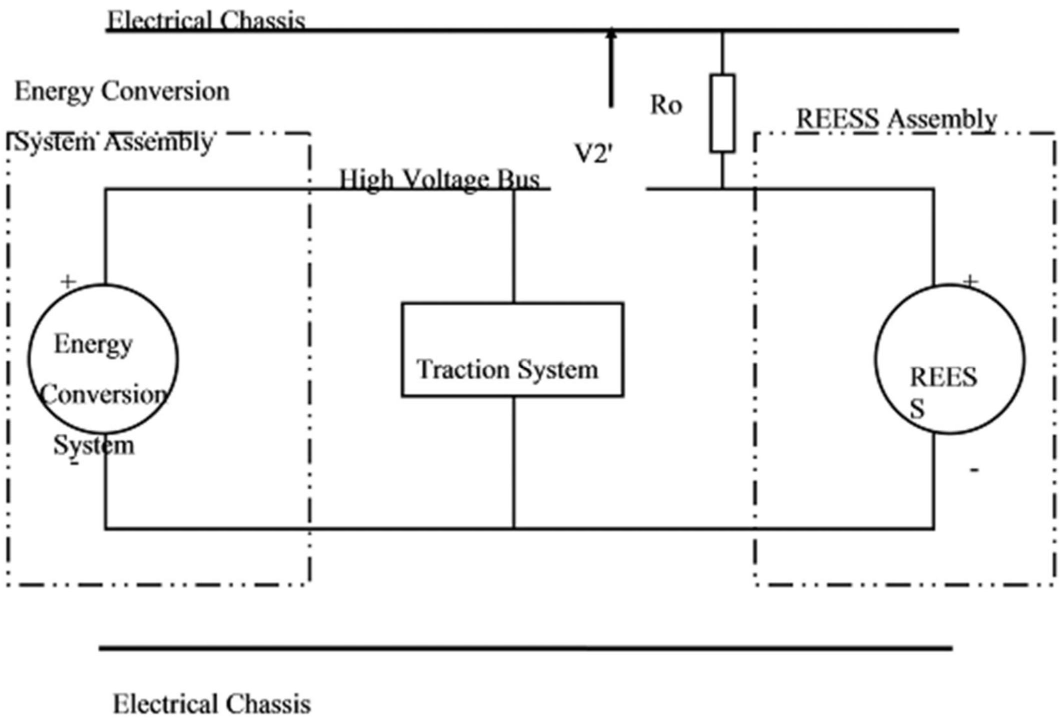


Figure 4-Ap1-3

Measurement of V2'

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 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.

Appendix 2 – Confirmation method for function of on-board isolation resistance monitoring system

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

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

Appendix 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 4-Ap3-1.

2. Test conditions

The access probe is pushed against any openings of the enclosure with the force specified in Table 4-Ap3-1. 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 ≥ 40 V and ≤ 50 V in series with a suitable lamp shall be connected, if necessary, between the probe and live parts inside the barrier or enclosure.

The signal-circuit method shall also be applied to the moving live parts of high voltage equipment.

Internal moving parts may be operated or otherwise repositioned 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 up.

In the case of the test for IPXXB, the jointed test finger may penetrate to its 80 mm length, but the stop face (diameter 50 mm x 20 mm) shall not pass through the opening. Starting from the straight position, both joints of the test finger shall be successively bent through an angle of up to 90 degree with respect to the axis of the adjoining section of the finger and shall be placed in every possible position.

In case of the tests for IPXXD, the access probe may penetrate to its full length, but the stop face shall not fully penetrate through the opening.

First numeral	Addit. letter	Access probe	Test force
2	B	Jointed test finger See Figure 4-Ap3-1 below for full dimensions	10 N ± 10%

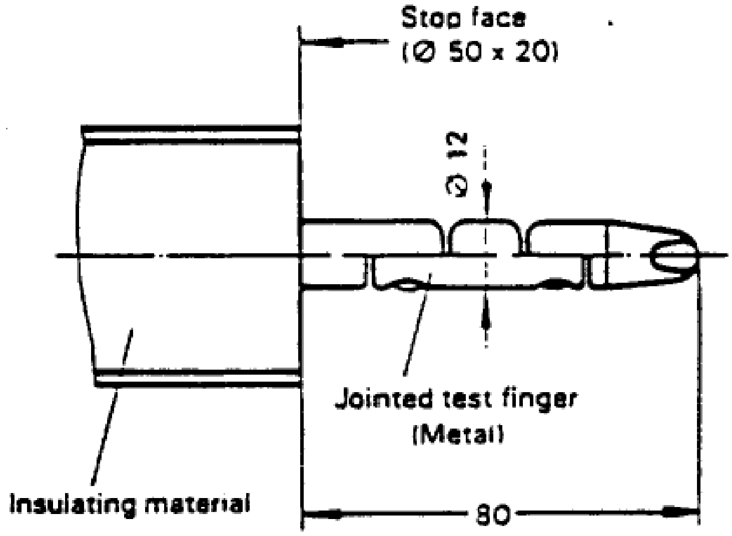
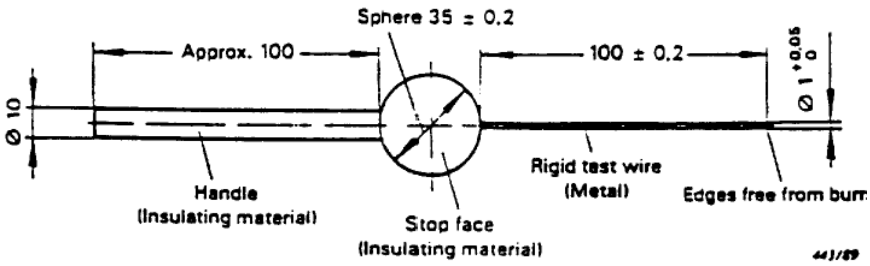
			
4, 5, 6	D	Test wire 1.0 mm diameter 100 mm long 	1 N ± 10%

Table 4-Ap3-1

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

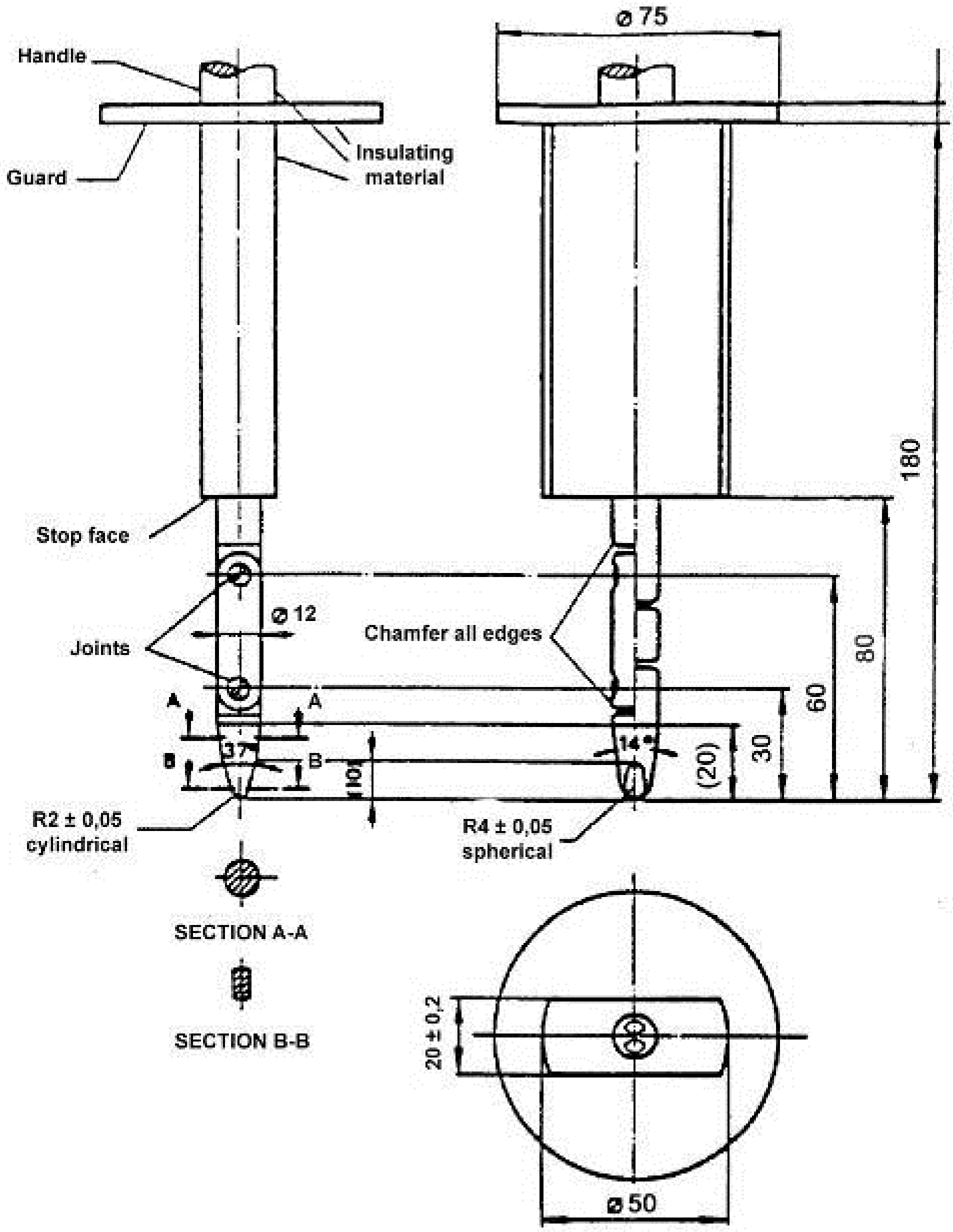


Figure 4-Ap3-1

Jointed test finger

Definitions

(1) ‘type of vehicle with regard to electrical safety’ means vehicles which do not differ in such essential respects as the location of conducting parts and components of the entire electrical system installed in the vehicle, the installation of the electric powertrain and the galvanically connected high voltage bus as well as the nature and type of electric powertrain and the galvanically connected high voltage components ;

(2) ‘active driving possible mode’ means the vehicle mode when application of the electric acceleration position sensor, activation of an equivalent control or release of the brake system will cause the electric powertrain to propel the vehicle;

(3) ‘barrier’ means the part providing protection against direct contact to the live parts from any direction of access;

(4) ‘conductive connection’ means the connection using connectors to an external power supply when the rechargeable energy storage system (REESS) is charged;

(5) ‘REESS’ means the rechargeable electric energy storage system that provides energy for electric propulsion;

(6) ‘coupling system for charging the REESS’ means the electrical circuit used for charging the REESS from an external electric power supply including the vehicle inlet;

(7) ‘direct contact’ means the contact of persons with live parts;

(8) ‘electrical chassis’ means a set made of conductive parts electrically linked together, whose potential is taken as reference;

(9) ‘electrical circuit’ means an assembly of connected live parts which is designed to be electrically energized in normal operation;

(10) ‘electric energy conversion system’ means a system that generates and provides electric energy for electric propulsion;

(11) ‘electric powertrain’ means the electrical circuit which includes the traction motor(s), and includes the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the REESS;

(12) ‘electronic converter’ means a device capable of controlling and/or converting electric power for electric propulsion;

(13) ‘enclosure’ means the part enclosing the internal units and providing protection against direct contact from any direction of access;

(14) ‘exposed conductive part’ means the conductive part which can be touched under the provisions of the protection degree IPXXB, and which becomes electrically energized under isolation failure conditions;

(15) ‘external electric power supply’ means an alternating current (AC) or direct current (DC) electric power supply outside of the vehicle;

(16) ‘high voltage’ means the classification of an electric component or circuit, if it’s working voltage is > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC root mean square (rms);

(17) ‘high voltage bus’ means the electrical circuit, including the coupling system for charging the REESS that operates on high voltage;

(18) ‘indirect contact’ means the contact of persons with exposed conductive parts;

(19) ‘live parts’ means the conductive part(s) intended to be electrically energized in normal use;

(20) ‘luggage compartment’ means the space in the vehicle for luggage accommodation, bounded by the roof, bonnet, trunk lid or rear door and floor and side walls, as well as by the barrier and enclosure provided for protecting the powertrain from direct contact with live parts, being separated from the passenger compartment by the front or rear bulkhead;

(21) ‘on-board isolation resistance monitoring system’ means the device which monitors the isolation resistance between the high voltage buses and the electrical chassis;

(22) ‘open type traction battery’ means a liquid type battery requiring refilling with water and generating hydrogen gas released to the atmosphere;

(23) ‘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 powertrain from direct contact with live parts;

(24) ‘protection degree’ means the protection provided by a barrier or enclosure related to the contact with live parts by a test probe, such as a jointed test finger (IPXXB) or a test wire access probe (IPXXD);

(25) ‘service disconnect’ means the device for deactivation of the electrical circuit for the purpose of servicing or checking electrical components such as the REESS and fuel cell stack;

(26) ‘solid insulator’ means the insulation coating of wiring harnesses insulating live parts against direct contact from any direction of access, covers insulating live parts of connectors, as well as varnish or paint applied for the purpose of insulation;

(27) ‘working voltage’ means the highest value of an electrical circuit voltage root-mean-square (rms) as specified by the vehicle manufacturer for each separate and galvanically isolated circuit, which may occur between any conductive parts in open circuit conditions or under normal operating condition;