ELSA 4th meeting, November 14, 2008

ELECTRICAL SAFETY PROVISIONS FOR VEHICLES Post Crash

1. General

~~This part specifies electrical safety requirements for electric vehicles, hybrid vehicles and fuel cell vehicles following vehicle crash test(s).~~

This module shall apply to the **electric** power train of electric vehicles, hybrid vehicles and fuel cell vehicles, and the high voltage components and systems which are galvanically connected to the high voltage bus of the **electric** power train following vehicle crash test(s). The crash test(s) to be used for purposes of evaluating compliance to these requirements are those specified within existing regulations of the contracting parties.

2. ~~Terms and~~ Definitions

For the purposes of this ~~document~~ regulation~~,~~ the following ~~terms and~~ definitions apply.

~~electrical isolation~~

~~the electrical resistance between the vehicle high-voltage source and any vehicle conductive structure.~~

2-1 Electric power train

the electrical circuit which may include the RESS, the energy conversion system, the electronic converters, the traction motors, the associated wiring harness and connectors, and the coupling system for charging the RESS

~~energy storage system~~

~~the components comprising, but not limited to, the vehicle's high-voltage battery system or capacitor system. These include, but are not limited to, the battery or capacitor modules, interconnects, venting systems, battery or capacitor restraint devices, and energy storage boxes or containers that hold the individual battery or capacitor modules.~~

2-2 "RESS"

Rechargeable energy storage system that provides the electric energy for propulsion

~~rechargeable energy storage system (RESS)~~

~~system that stores energy for delivery of electric energy and which is rechargeable~~

2-3 Energy conversion system

system that generates and provides electric energy for propulsion.

2-4 Electronic converter

a device capable of controlling or converting electric power.

2-5 Coupling system for charging the RESS

the electrical circuit used for charging the RESS from an **external electric power supply (AC or DC electric power supply outside of the vehicle) including the vehicle inlet**

~~**2-6 External electric power supply**~~

~~**an AC or DC electric power supply outside of the vehicle.**~~

2–7 Passenger compartment

the space for occupant accommodation, bounded by the roof, floor, side walls, doors, window glass, front bulkhead and rear bulkhead, or rear gate, as well as by the barriers and enclosures provided for protecting the power train from direct contact with live parts.

2–8 Luggage compartment

the space in the vehicle for luggage accommodation, bounded by the roof, hood, floor, side walls, as well as by the barrier and enclosure provided for protecting the power train from direct contact with live parts, being separated from the passenger compartment by the front bulkhead or the rear bulk head.

2–9 Direct contact

the contact of persons with live parts.

2–10 Live parts

conductive part(s) intended to be electrically energized in normal use.

2–11 Indirect contact

the contact of persons with exposed conductive parts.

2–12 Protection degree

Protection provided by a barrier/enclosure related to the contact with live parts by a test probe, such as a test finger (IPXXB), ~~a test rod (IPXXC),~~ or a test wire (IPXXD) as defined in ~~ISO 20653~~ Attached Sheet 1

[2–13 Exposed conductive part

conductive part which can be touched, ~~**under the provisions of the protection degree IPXXB,**~~ and which only becomes electrically energized under failure conditions.]

2–14 Electrical circuit

an assembly of connected live parts which is designed to be electrically energized in normal operation.

2–15 Working voltage

the highest value of an electrical circuit voltage, specified by the manufacturer, which may occur between any conductive parts in open circuit conditions or under normal operating conditions.

2–16 Electrical chassis

a set made of conductive parts electrically linked together, whose potential is taken as reference.

2–17 Solid insulator

insulating coating of wiring harnesses provided in order to cover and protect the live parts against direct contact from any direction of access; covers for insulating the live parts of connectors; and varnish or paint for the purpose of insulation.

2–18 Barrier

the part providing protection against direct contact to the live parts from any direction of access.

2–19 Enclosure

the part enclosing the internal units and providing protection against direct contact from any ~~**usual**~~ direction of access.

~~**2–20 Service plug**~~

~~**the device for shutting off the electrical circuit when conducting checks and services of the traction battery, fuel cell stack, etc.**~~

~~**2-21 On-board isolation resistance monitoring system**~~

~~**the device which monitors the isolation resistance between the high voltage buses and the electrical chassis.**~~

~~high-voltage source~~
~~any item that produces voltage levels equal to or greater than 30 VAC or 60 VDC.~~
~~VAC~~
~~volts of alternating current (AC).~~
~~VDC~~
~~volts of direct current (DC).~~

2-22 High Voltage

classification of an electric component or circuit, if its maximum working voltage is > 60 V and ≤ [1500] V d.c. or > 30 V and ≤ [1000] V a.c. ~~**respectively**~~

2-23 High Voltage Bus

electrical circuit, including the coupling system for charging the RESS, that operates on high voltage

3. Requirements

During and after the specified crash test(s), ~~fuel cell~~ vehicles ~~to which this standard applies~~ shall meet the performance requirements specified in paragraphs 3~~2~~.1 through 3~~2~~.3. ~~Each vehicle to which this standard applies must be capable of meeting the requirements of any applicable single barrier crash/static rollover test sequence, without alteration of the vehicle during the test sequence. A particular vehicle need not meet further test requirements after having been subjected to a single barrier crash/static rollover test sequence.~~

3-1 [Electrolyte spillage from RESS

Not more than 5.0 liters of electrolyte from propulsion batteries shall spill outside the passenger compartment, and no visible trace of electrolyte shall spill into the passenger compartment, within ~~Spillage is measured from the time the vehicle ceases motion after a barrier impact test until~~ 30 minutes ~~thereafter, and throughout any static rollover~~ after a barrier impact test. Compliance may be demonstrated by test or analysis.]

3-2 **[Traction battery** ~~**RESS**~~ retention

Battery modules located inside the passenger compartment must remain in the location in which they are installed. No part of any battery system component that is located outside the passenger compartment shall enter the passenger compartment during the test procedures ~~of S6 of this standard~~, as determined by visual inspection.]

3-3 [Electrical Safety

~~Within 5 seconds of the vehicle coming to rest after each crash test, electrical safety shall be provided as follows:~~

~~(a) For AC high-voltage systems, at least one of the following criteria shall be met:~~
~~(1) Electrical isolation between any high-voltage source and the vehicle chassis electricity-conducting structure greater than or equal to [500] ohms/nominal volt; or~~
~~(2) Voltage of the bus equal to or less than 30 VAC; or~~
~~(3) Energy on the bus less than 0.2 Joules; or~~
~~(4) The AC high-voltage bus is fully enclosed and isolated within a physical barrier that provides protection class IPXXB.~~

~~(b) For DC high-voltage systems, at least one of the following criteria shall be met:~~
~~(1) Electrical isolation between any high-voltage source and the vehicle chassis~~

~~electricity-conducting structure greater than or equal to [100] ohms/nominal volt; or~~
~~(2) Voltage of the bus equal to or less than 60 VDC; or~~
~~(3) Energy on the bus less than 0.2 Joules; or~~
~~(4) The DC high-voltage bus is fully enclosed and isolated within a physical enclosure or barrier that provides protection class IPXXB.~~

After each crash test, at least one of the following criteria specified in paragraph 3-3-1 thorough paragraph 3-3-4 shall be met. If the vehicle has an automatic disconnect function, the criteria shall be applied to each divided portion individually.

3-3-1 Isolation Resistance

If the electrical circuit divided by the disconnect function includes AC circuit, this part of the high voltage bus shall be considered as an AC high voltage bus.
If the electrical circuit divided by the disconnect function doesn't include AC circuit, this part of the high voltage bus shall be considered as a DC high voltage bus.

3-3-1-1 For AC high voltage buses, isolation resistance between the high voltage bus and the electrical chassis shall have minimum value of 500 ohms/volt of working voltage.
If the protection degree IPXXB is satisfied for AC portion of the high voltage buses after crash, isolation resistance between the high voltage bus and the electrical chassis shall have minimum value of 100 ohms/volt of working voltage.

3-3-1-2 For DC high voltage buses, isolation resistance between any high voltage bus and the electrical chassis shall have minimum value of 100 ohms/volt of working voltage.

3-3-2 Voltage

3-3-2-1 For AC high voltage buses, voltage of the bus shall be equal to or less than 30 VAC.
3-3-2-2 For DC high voltage buses, voltage of the bus shall be equal to or less than 60 VDC.

3-3-3 Energy

Energy on the high voltage bus shall be less than 0.2 Joules.

3-3-4 Physical Protection

3-3-4-1 For protection of live parts, the protection degree IPXXB shall be provided.
3-3-4-2 For protection against indirect contact with live parts, all exposed **conductive parts** **~~electro conductive components~~** shall be securely connected to the electrical chassis such that no dangerous potentials are produced. The resistance between the electrical chassis and all conductive **parts** **~~electro conductive components~~** shall be less than 0.1 ohm, which is measured when there is a current flow of at least 0.2 amps.
The said resistance shall be regarded as lower than 0.1 ohm when it is clearly evident that the DC electrical connection has been established adequately and securely by welding.]

4. Test Conditions

The test conditions specified in paragraphs 4-1 and 4-2 shall be used. Where a range is specified, the vehicle must be capable of meeting the requirements at all points within the range.

4-1 Vehicle conditions

4-1-1 ~~The switch or device that provides power from the propulsion RESS to the propulsion motor(s) is in the activated position or the ready-to-drive position~~

The high voltage system shall be ~~connected to the vehicle propulsion system, and the vehicle ignition in the ready to drive position 'on ready' (high voltage system and auxiliary system)~~ energized ~~position~~.

~~However in the case that the engine combustion system is required in order to make the high voltage system energized, the vehicle ignition may be in the 'on' (auxiliary system energized) position.~~

4-1-2 ~~The parking brake is disengaged and the transmission, if any, is in the neutral position. [In a test conducted under S6.3, the parking brake is set.~~

~~Tires are inflated to the manufacturer's specifications.~~

~~The vehicle is loaded as specified in the crash test protocols of the contracting parties, including necessary test dummies, restrained only by means that are installed in the vehicle for protection at its seating position.~~

The vehicle conditions other than specified in 4-1-1 shall be in the crash test protocols of the contracting parties.

4-2 RESS state of charge

The RESS is at the level specified in the following paragraph (a), (b), or (c), as appropriate:

(a) At the maximum state of charge recommended by the manufacturer, as stated in the vehicle operator's manual or on a label that is permanently affixed to the vehicle;

(b) If the manufacturer has made no recommendation, at a state of charge of not less than 95 percent of the maximum capacity of the RESS; or

(c) If the RESS are rechargeable only by an energy source on the vehicle, at any state of charge within the normal operating voltage, as defined by the vehicle manufacturer.

4-3 Energy conversion system

Proposal from OICA together with JAISIC

5. Test Procedures

This section describes test procedures ~~that may be used to determine electrical voltage, isolation and energy levels between the fuel cell vehicle high voltage systems and the vehicle conducting structure~~ demonstrate compliance to the electrical safety requirements of paragraph 3-3. ~~may be used to determine electrical voltage, isolation resistance and energy levels between the high voltage bus and the electrical chassis.~~ [Alternative test and analysis methods may also be used.] ~~to demonstrate compliance to the electrical safety requirements of paragraph 3-3.~~ For example, megohmmeter measurements are an appropriate alternative to the procedure described below for measuring isolation resistance. [Well-established calculation methods also exist to determine electrical energy on high voltage buses.]

The following procedures should be performed ~~before and~~ after each of the specified crash tests.

5-1 Test setup and equipment

~~The high voltage system shall be connected to the vehicle propulsion system, and the vehicle ignition shall be in the 'on' (high voltage system energized) position.~~

If a high voltage disconnect function is used, ~~and the disconnect function is integral to the energy RESS~~ measurements are taken from both ~~the RESS side or the energy conversion system side and the traction system~~ sides of the device performing the disconnect function.

However, if the high voltage disconnect is integral to the RESS or the energy conversion system and the high-voltage bus of the RESS or the energy conversion system is fully enclosed within a physical barrier or enclosure that maintains protection class IPXXB after crash test, measurements may be taken only downstream of the device performing the disconnect function.

~~If a high voltage disconnect function is used and the disconnect function is not integral to the RESS, measure the voltage upstream of the device performing the disconnect function.~~

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

~~NOTE: Meter resistance is neglected in the calculation of electrical isolation in that which follows.~~

5-2 Bus voltage

The following instructions may be used if voltage is measured.
[Prior to the vehicle crash test measure and record the high voltage bus voltage (Vb) (see Figure 1 ~~2~~). If Vb is high voltage, conduct the specified vehicle crash test]. After the crash test, determine the high voltage bus voltages (Vb, V1, V2) (see Figure 1 ~~2~~). [If the ~~Energy Storage Device Assembly~~ RESS ~~is designed to be isolated with respect to vehicle chassis~~ has exposed conductive parts ~~portions~~, measure the voltage V3 between any exposed conductive parts ~~portions~~ of it and the electrical chassis.]
The measurement shall be made ~~immediately~~ after [5 seconds of] the vehicle coming to rest after each crash test.

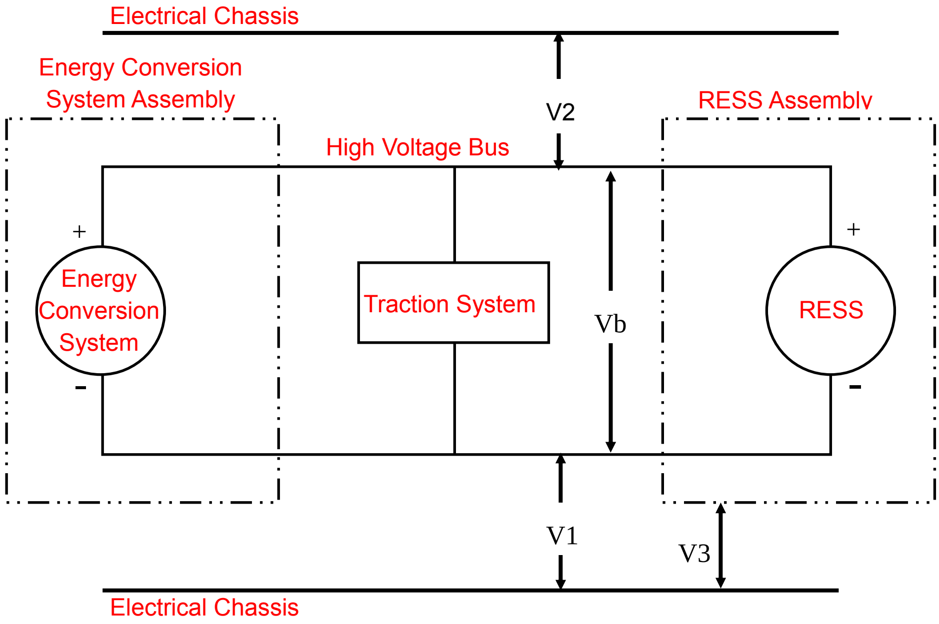


Figure 1~~2~~: Measurement of Vb, V1, V2

5-3 ~~Electrical~~ Resistance isolation

The following instructions may be used if isolation resistance is measured.
[Before the vehicle crash test, measure and record the high voltage bus voltage (Vb) (see Figure 1~~2~~). Vb must be equal to or greater than the nominal operating voltage as defined by the vehicle manufacturer.]

[It is acceptable for vehicle manufacturer to elect to calculate or simulate this value instead of measuring this after the crash.]

Measure and record the voltage (Vb) between the negative and the positive side of the high voltage bus (see Figure 1):

Measure and record the voltage (V1) between the negative side of the high voltage bus and the ~~vehicle~~ electrical chassis (see Figure 1~~2~~):

Measure and record the voltage (V2) between the positive side of the high voltage bus and the electrical chassis (see Figure 1~~2~~):

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 ~~vehicle~~ electrical chassis. With Ro installed, measure the voltage (V1') between the negative side of the high voltage bus and the vehicle electrical chassis (see Figure 2~~3~~). Calculate the ~~electrical~~ isolation resistance (Ri) according to the formula shown. Divide this electrical isolation resistance value (in ohms) by the ~~nominal operating~~ working voltage of the high voltage bus (in volts).

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

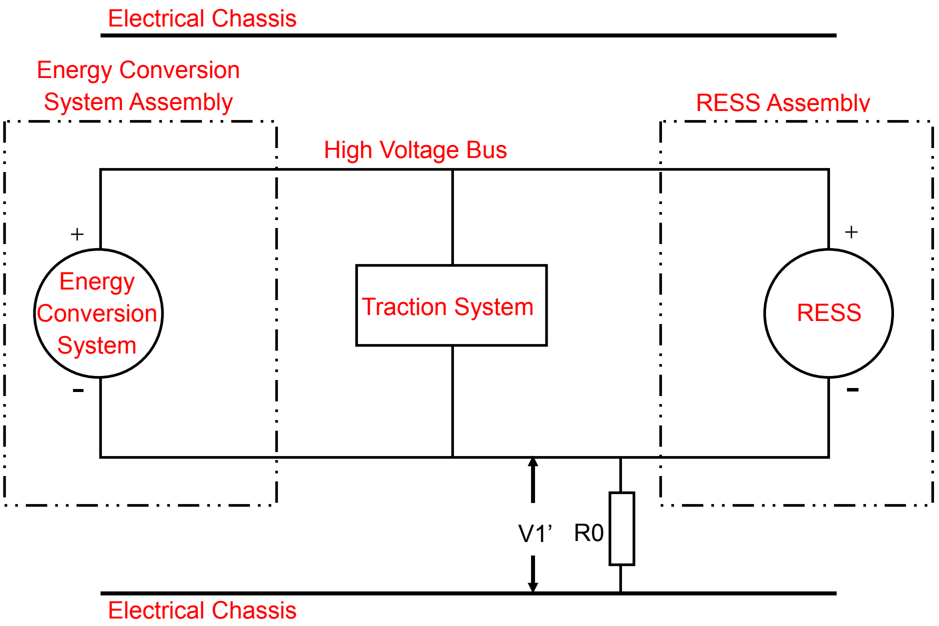


Figure 2~~3~~: Measurement of V1'

If V2 is greater than V1, insert a standard known resistance (Ro) between the positive side of the high voltage bus and the ~~vehicle~~ electrical chassis. With Ro installed, measure the voltage (V2') between the positive side of the high voltage bus and the electrical ~~vehicle~~ chassis (See Figure 3~~4~~).
Calculate the ~~electrical~~ isolation resistance (Ri) according to the formula shown. Divide this electrical isolation value (in ohms) by the ~~nominal operating~~ working voltage of the high voltage bus (in volts).

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

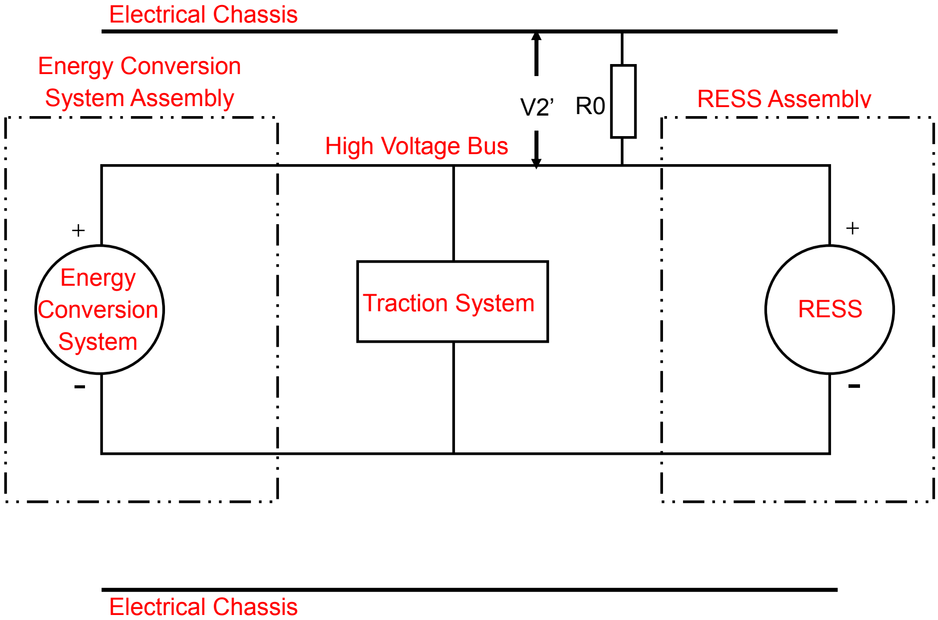


Figure ~~3~~4: Measurement of V2'

NOTE 1: The standard known resistance Ro (in ohms) should be approximately 500 times the ~~nominal operating~~ working voltage of the vehicle (in volts). Ro is not required to be precisely this value since the equations are valid for any Ro; however, an Ro value in this range should provide good resolution for the voltage measurements.

~~NOTE 2: If the isolation resistance is calculated to be between 500 ohms/volt and 250 ohms/volt, additional calculations may be required to determine the location and number of ground faults and the resulting worst-case leakage current.~~

5-4 Electrical Energy

The following procedure may be used if energy is measured.
After the vehicle crash determine the high voltage bus energy (see Figure 4~~5~~). Install switch S1 and known resistance Re. Close switch S1 and measure and record voltage Vb and current Ie. [Integrate the product of these two measurements with respect to time as shown below to obtain total energy.]

$$\int_{t_0}^{t_1} V_b \times I_e dt$$

t_0 = ???
t_1= ???

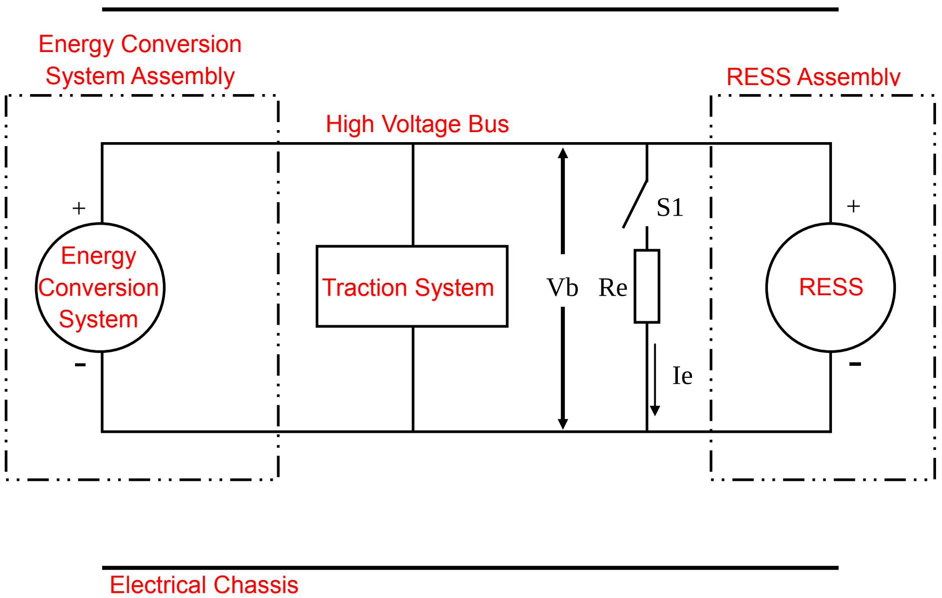


Figure 4~~5~~: Measurement of high voltage bus energy

5-5 Physical Barrier

5-5-1 Test conditions

The manufacturer shall define the barrier, enclosure and solid insulator that protect the human from the direct contact to the high voltage bus in use (hereinafter referred to as the 'original physical protection').

Any surrounding parts of the high voltage components that can be opened, disassembled or removed without the use of tools after crash test shall be opened, disassembled or removed. Surrounding parts that cannot be opened, disassembled or removed without the use of tools are considered as a part of the physical barrier.

The access probe is pushed against any openings of the physical barrier with the force specified in table 1. If it partly or fully penetrates into the original physical protection, it is placed in every possible position.

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.

5-5-2 Acceptance conditions

~~The protection is satisfactory if adequate clearance is kept between the access probe and hazardous parts.~~

[The access probe shall not touch ~~hazardous~~ live parts.]

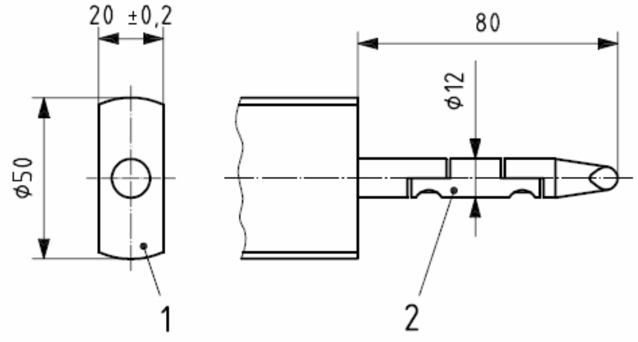
A mirror or a fiberscope may be used in order to inspect whether the access probe touches the high voltage buses, if necessary.

Attached Sheet 1

PROTECTION DEGREES

1 IPXXB

Jointed test finger diameter 12; 80 length Dimensions in millimetres



Key

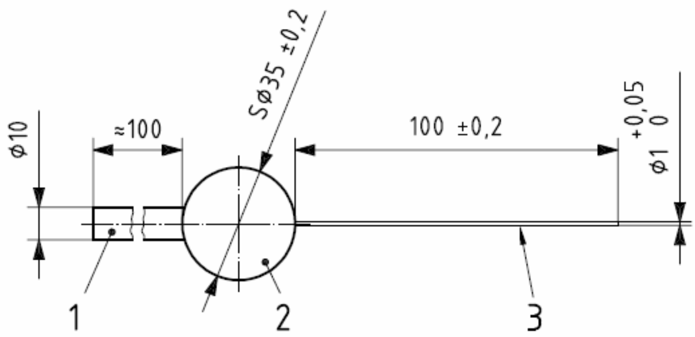
1 stop face (diameter 50 × 20) (insulating material)

2 jointed test finger (metal)

The jointed test finger may penetrate over its full length of 80 mm but shall not contact ~~be sufficiently distant from~~ the hazardous parts, even when its joints are bent at any optional angle (up to 90° from its axis) and are brought into any possible position. The stop face (Ø50 mm · 20 mm) shall not pass through the opening.
The test force shall be 10 N ± 10 %.

2 IPXXD

Test wire diameter 1,0; 100 long Dimensions in millimetres



Key

1 handle (insulating material)

2 stop face (insulating material)

3 sphere

4 rigid test wire (metal) (edges free from burrs)

The rigid test wire (diameter 1,0 mm, 100 mm long) may penetrate over its full length of 100 mm, but shall be sufficiently distant from hazardous parts in any possible angular position. The stop face (sphere Ø35 mm) shall not pass through the opening.
The test force shall be 1 N ± 10 %.