

## 46-1 The protection of the occupants in the event of a frontal collision

Refer to: R94 02-S2

### 46-1.1 Effective Date and Scope:

46-1.1.1 As for the power-driven vehicles of category M1 of a total permissible mass not exceeding or equal to 2.5 tons, all vehicle variants from 2014/1/1, shall comply with this regulation.

46-1.1.2 For the non-electric vehicles with “460 The protection of the occupants in the event of a frontal collision” approval documents, it could be deemed to comply with this regulation.

46-1.1.3 Except for child-only vehicle, application for low volume or vehicle-by-vehicle safety approval may be exempt from this regulation

### 46-1.2 Definitions

#### 46-1.2.1 “Passenger Compartment” :

46-1.2.1.1 “Passenger compartment with regard to occupant protection” means the space for occupant accommodation, bounded by the roof, floor, side walls, doors, outside glazing and front bulkhead and the plane of the rear compartment bulkhead or the plane of the rear-seat back support.

46-1.2.1.2 “Passenger compartment for electric safety assessment” means the space for occupant accommodation, bounded by the roof, floor, side walls, doors, outside glazing, front bulkhead and rear bulkhead, or rear gate, as well as by the electrical protection barriers and enclosures provided for protecting the power train from direct contact with high voltage live parts.

46-1.2.2 “High Voltage” means the classification of an electric component or circuit, if its working voltage is  $> 60\text{ V}$  and  $\leq 1,500\text{ V}$  direct current (DC) or  $> 30\text{ V}$  and  $\leq 1,000\text{ V}$  alternating current (AC) root-mean-square (rms).

46-1.2.3 “RESS” means rechargeable energy storage system that provides the electric energy for propulsion.

46-1.2.4 “Electrical Protection Barrier” means the part providing protection against any direct contact to the high voltage live parts.

46-1.2.5 “Electrical power train” means the electrical circuit which includes the traction motor(s), and may also include the RESS, the electrical energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the RESS.

46-1.2.6 “Live parts” means conductive part(s) intended to be electrically energized in normal use.

46-1.2.7 “Exposed conductive part” means the conductive part which can be touched under the provisions of the protection IPXXB, and which becomes electrically energized under isolation failure conditions. This includes parts under a cover that can be removed without using tools.

46-1.2.8 “Direct contact” means the contact of persons with high voltage live parts.

46-1.2.9 “Indirect contact” means the contact of persons with exposed conductive parts.

46-1.2.10 “Protection IPXXB” means protection from contact with high voltage live parts provided by either an electrical protection barrier or

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an enclosure and tested using a Jointed Test Finger (IPXXB) as described.

46-1.2.11 “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 conditions. If the electrical circuit is divided by galvanic isolation, the working voltage is defined for each divided circuit, respectively.

46-1.2.12 “Coupling system for charging the rechargeable energy storage system (RESS)” means the electrical circuit used for charging the RESS from an external electrical power supply including the vehicle inlet.

46-1.2.13 “Electrical chassis” means a set made of conductive parts electrically linked together, whose electrical potential is taken as reference.

46-1.2.14 “Electrical circuit” means an assembly of connected high voltage live parts which is designed to be electrically energized in normal operation.

46-1.2.15 “Electrical energy conversion system” means a system (e.g. fuel cell) that generates and provides electrical energy for electrical propulsion.

46-1.2.16 “Electronic converter” means a device capable of controlling and/or converting electrical power for electrical propulsion.

46-1.2.17 “Enclosure” means the part enclosing the internal units and providing protection against any direct contact.

46-1.2.18 “High Voltage Bus” means the electrical circuit, including the coupling system for charging the RESS that operates on a high voltage.

46-1.2.19 “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. This includes covers for insulating the high voltage live parts of connectors; and varnish or paint for the purpose of insulation.

46-1.2.20 “Automatic disconnect” means a device that when triggered, galvanically separates the electrical energy sources from the rest of the high voltage circuit of the electrical power train.

46-1.2.21 “Open type traction battery” means a type of battery requiring liquid and generating hydrogen gas released to the atmosphere.

46-1.3 The protection of the occupants in the event of a frontal collision shall according to suitable types and range of principle are as below :

46-1.3.1 Vehicle powered by internal combustion engine:

46-1.3.1.1 The same vehicle category symbol.

46-1.3.1.2 The same axle set type.

46-1.3.1.3 The same brand and vehicle type series.

46-1.3.2 Vehicle powered by an electric motor:

46-1.3.2.1 The same vehicle category.

46-1.3.2.2 The same axle set variant.

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46-1.3.2.3 The same brand and vehicle type.

46-1.3.2.4 The same place of the components of the propulsion system.

46-1.3.2.5 The same place of the battery or of the parts of propulsion battery.

#### 46-1.4 State of vehicle:

46-1.4.1 For the test, the mass of the vehicle submitted shall be the unladen kerb mass; The fuel tank shall be filled with water to mass equal to 90 % of the mass of a full as specified by the manufacturer with a tolerance of +/- 1 %.

It shall be allowed by agreement between manufacturer and Technical Service to modify the fuel system so that an appropriate amount of fuel can be used to run the engine or the electrical energy conversion system. This requirement does not apply to Hydrogen fuel tanks.

46-1.4.2 The mass of the measuring apparatus shall not change each axle reference load by more than 5%, each variation not exceeding 20 kg.

46-1.4.3 The doors shall be closed but not locked. The gear-change lever shall be in the neutral position.

46-1.4.4 Front seats adjustable longitudinally shall be placed so that their "H" point is in the middle position of travel or in the nearest locking position thereto, and at the height position defined by the manufacturer (if independently adjustable for height). Head restraints adjustable for height shall be in their uppermost position. If adjustable, the seat-backs shall be adjusted so that the resulting inclination of the torso of the dummy is as close as possible to that recommended by the manufacturer for normal use or, in the absence of any particular recommendation by the manufacturer, to 25 degrees towards the rear from the vertical. The steering wheel, if adjustable, shall be placed in the normal position indicated by the manufacturer or, failing that, midway between the limits of its range(s) of adjustment. If adjustable, the rear seats shall be placed in the rearmost position.

46-1.4.5 A dummy corresponding to the specifications for Hybrid III (corresponding to the principal dimensions of a fiftieth percentile male), with safety belt complying with the specifications specified in the "Standards" and safety-belt anchorages complying with the specifications specified in this "Standards" shall be installed in each of the front outboard seats.

#### 46-1.4.6 Electric power train adjustments

46-1.4.6.1 The RESS shall be at any state of charge, which allows the normal operation of the power train as recommended by the manufacturer.

46-1.4.6.2 The electrical power train shall be energized with or without the operation of the original electrical energy sources (e.g. engine-generator, RESS or electric energy conversion system), however:

46-1.4.6.2.1 By the agreement between Technical Service and manufacturer it shall be permissible to perform the test with all or parts of the electrical power train not being energized insofar as there is no negative influence on the test result.

For parts of the electrical power train not energized, the protection against electrical shock shall be proved by either

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physical protection or isolation resistance and appropriate additional evidence.

46-1.4.6.2.2 In the case where an automatic disconnect is provided, at the request of the manufacturer it shall be permissible to perform the test with the automatic disconnect being triggered. In this case it shall be demonstrated that the automatic disconnect would have operated during the impact test. This includes the automatic activation signal as well as the galvanic separation considering the conditions as seen during the impact.

46-1.5 Test methods: The vehicle shall be propelled either by its own engine or by any other propelling device. Vehicle speed at the moment of impact shall be 56 -0/ +1 km/h and the front face of the barrier (consisting of block and aluminum honeycomb) is perpendicular to the direction of travel of the test vehicle. At the moment of impact the vehicle shall no longer be subject to the action of any additional steering or propelling device. The orientation of the barrier is such that the first contact of the vehicle with the barrier is on the steering-column side. The vehicle shall overlap the barrier face by 40 % +/- 20 mm.

46-1.6 Specifications: The test of the vehicle carried out shall be considered satisfactory if all the conditions set out, shall meet the following requirements.

Additionally, vehicles equipped with electric power train shall meet the requirements of paragraph 46-1.6.5. This can be met by a separate impact test at the request of the manufacturer and after validation by the Technical Service, provided that the electrical components do not influence the occupant protection performance of the vehicle type as defined in paragraphs 46-1.6.1. to 46-1.6.4. of this Regulation. In case of this condition the requirements of paragraph 46-1.6.5. shall be checked in accordance with the methods set out of paragraph 46-1.4.. But a dummy corresponding to the specifications for Hybrid III fitted with a 45° angle and meeting the specifications for its adjustment shall be installed in each of the front outboard seats.

46-1.6.1 The performance criteria recorded on the dummies in the front outboard seats shall meet the following conditions:

46-1.6.1.1 The head performance criterion (HPC) shall not exceed 1000 and the resultant head acceleration shall not exceed 80 g for more than 3 ms. The latter shall be calculated cumulatively, excluding rebound movement of the head; (Values of HPC for which the time interval (t1 - t2) is greater than 36 ms are ignored for the purposes of calculating the maximum value).

46-1.6.1.2 The neck injury criteria:

46-1.6.1.2.1 The neck injury criteria (NIC) shall not exceed the values shown in Fig. 1 and 2;

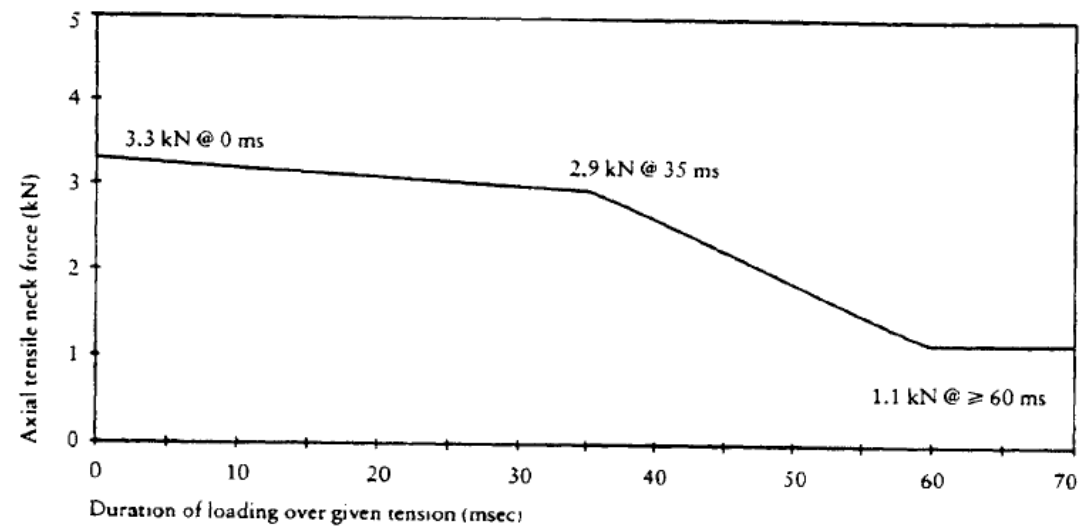


Fig 1 : Neck Tension criterion

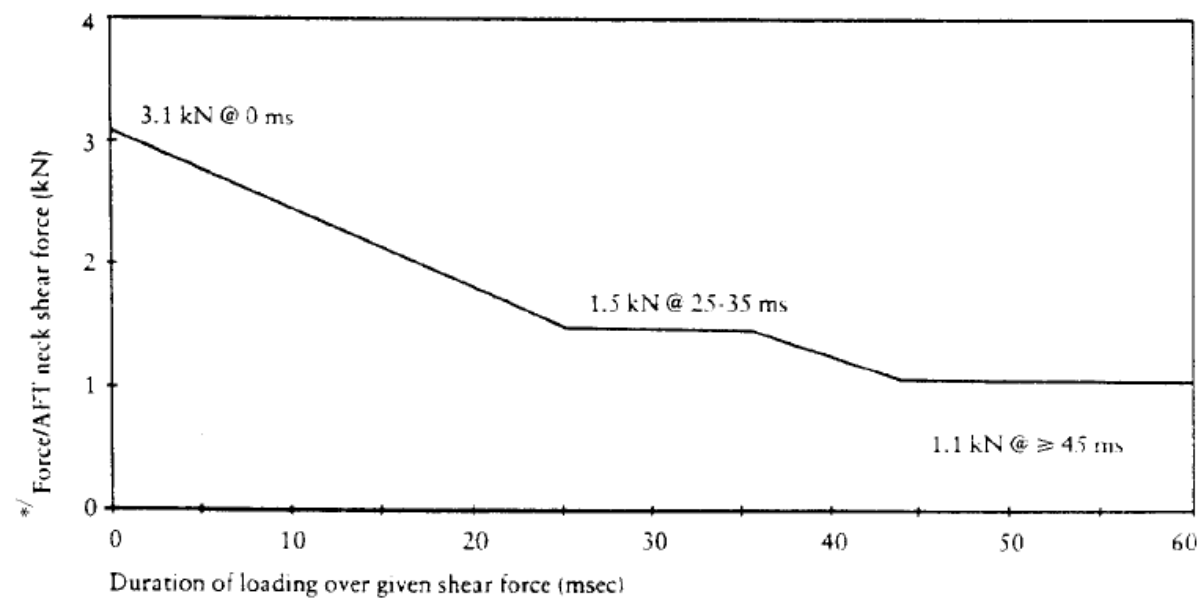


Fig 2 : Neck Shear criterion

- 46-1.6.1.2.2 The neck bending moment about the y axis shall not exceed 57 Nm in extension.
- 46-1.6.1.3 The thorax injury criterion:
  - 46-1.6.1.3.1 The thorax compression criterion (ThCC) shall not exceed 50 mm.
  - 46-1.6.1.3.2 The viscous criterion ( $V^*C$ ) for thorax shall not exceed 1.0 m/s.
- 46-1.6.1.4 The femur force criterion (FFC) shall not exceed the force-time performance criterion shown in Fig. 3.

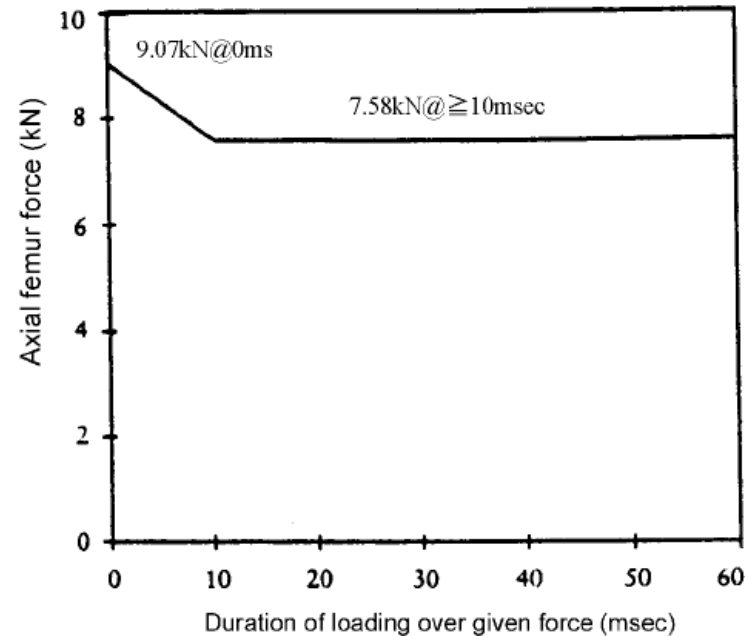


Fig 3 : Femur force criterion

46-1.6.1.5 Tibia injury criterion:

46-1.6.1.5.1 The tibia compression force criterion (TCFC) shall not exceed 8 kN.

46-1.6.1.5.2 The tibia index (TI), measured at the top and bottom of each tibia, shall not exceed 1.3 at either location.

46-1.6.1.6 The movement of the sliding knee joints shall not exceed 15 mm.

46-1.6.2 During the test no door shall open.

46-1.6.3 During the test no locking of the locking systems of the front doors shall occur.

46-1.6.4 After the impact, it shall be possible:

46-1.6.4.1 Without the use of tools, except for those necessary to support the weight of the dumm:

46-1.6.4.1.1 To open at least one door, if there is one, per row of seats and, where there is no such door, to move the seats or tilt their backrests as necessary to allow the evacuation of all the occupants; this is, however, only applicable to vehicles having a roof of rigid construction;

46-1.6.4.1.2 To release the dummies from their restraint system which, if locked, shall be capable of being released by a

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- maximum force of 60 N on the centre of the release control;
- 46-1.6.4.1.3 To remove the dummies from the vehicle without adjustment of the seats.
- 46-1.6.4.2 Residual steering wheel displacement, measured at the centre of the steering wheel hub, shall not exceed 80 mm in the upwards vertical direction and 100 mm in the rearward horizontal direction.
- 46-1.6.4.3 If there is continuous leakage of liquid from the fuel-feed installation after the collision, the rate of leakage shall not exceed 30 g/min; if the liquid from the fuel-feed system mixes with liquids from the other systems and the various liquids cannot easily be separated and identified, all the liquids collected shall be taken into account in evaluating the continuous leakage.
- 46-1.6.5 The electrical power train operating on high voltage, and the high voltage components and systems, which are galvanically connected to the high voltage bus of the electric power train, shall meet the following requirements:
- 46-1.6.5.1 Protection against electrical shock :
- After the impact at least one of the four criteria specified in paragraph 46-1.6.5.1.1. through paragraph 46-1.6.5.1.4.2. shall be met. If the vehicle has an automatic disconnect function, or device(s) that galvanically divide the electric power train circuit during driving condition, at least one of the following criteria shall apply to the disconnected circuit or to each divided circuit individually after the disconnect function is activated.
- However criteria defined in 46-1.6.5.1.4. shall not apply if more than a single potential of a part of the high voltage bus is not protected under the conditions of protection IPXXB.
- In the case that the test is performed under the condition that part(s) of the high voltage system are not energized, the protection against electrical shock shall be proved by either paragraph 46-1.6.5.1.3. or paragraph 46-1.6.5.1.4. for the relevant part(s).
- 46-1.6.5.1.1 Absence of high voltage : The voltages  $V_b$ ,  $V_1$  and  $V_2$  of the high voltage buses shall be equal or less than 30 VAC or 60 VDC as specified in paragraph 46-1.7.2.
- 46-1.6.5.1.2 Low electrical energy : The total energy (TE) on the high voltage buses shall be less than 2.0 joules when measured according to the test procedure as specified in paragraph 46-1.7.3. with the formula (a). Alternatively the total energy (TE) may be calculated by the measured voltage  $V_b$  of the high voltage bus and the capacitance of the X-capacitors ( $C_x$ ) specified by the manufacturer according to formula (b) of paragraph 46-1.7.3.
- The energy stored in the Y-capacitors ( $TE_{y1}$ ,  $TE_{y2}$ ) shall also be less than 2.0 joules. This shall be calculated by measuring the voltages  $V_1$  and  $V_2$  of the high voltage buses and the electrical chassis, and the capacitance of the Y-capacitors specified by the manufacturer according to formula (c) of paragraph 46-1.7.3.
- 46-1.6.5.1.3 Physical protection : For protection against direct contact with high voltage live parts, the protection IPXXB shall be provided. In addition, for protection against electrical shock which could arise from indirect contact, the resistance between all exposed conductive



parts and the electrical chassis shall be lower than 0.1 ohm when there is current flow of at least 0.2 ampere.

This requirement is satisfied if the galvanic connection has been made by welding.

#### 46-1.6.5.1.4 Isolation resistance :

The criteria specified in the paragraphs 46-1.6.5.1.4.1. and 46-1.6.5.1.4.2. below shall be met.

The measurement shall be conducted in accordance with paragraph 46-1.7.5.

##### 46-1.6.5.1.4.1 Electrical power train consisting of separate DC-or AC-buses :

If the AC high voltage buses and the DC high voltage buses are galvanically isolated from each other, isolation resistance between the high voltage bus and the electrical chassis ( $R_i$ , as defined in paragraph 46-1.7.5.) shall have a minimum value of  $100\Omega/V$  of the working voltage for DC buses, and a minimum value of  $500\Omega/V$  of the working voltage for AC buses.

##### 46-1.6.5.1.4.2 Electrical power train consisting of combined DC-and AC-buses :

If the AC high voltage buses and the DC high voltage buses are galvanically connected isolation resistance between the high voltage bus and the electrical chassis ( $R_i$ , as defined in paragraph 46-1.7.5.) shall have a minimum value of  $500\Omega/V$  of the working voltage.

However, if the protection IPXXB is satisfied for all AC high voltage buses or the AC voltage is equal or less than 30 V after the vehicle impact, the isolation resistance between the high voltage bus and the electrical chassis ( $R_i$ , as defined in paragraph 46-1.7.5.) shall have a minimum value of  $100\Omega/V$  of the working voltage.

#### 46-1.6.5.2 Electrolyte spillage :

In the period from the impact until 30 minutes after no electrolyte from the RESS shall spill into the passenger compartment and no more than 7 per cent of electrolyte shall spill from the RESS except open type traction batteries outside the passenger compartment. For open type traction batteries no more than 7 per cent with a maximum of 5.0 liters shall spill outside the passenger compartment.

The manufacturer shall demonstrate compliance in accordance with paragraph 46-1.7.6.

#### 46-1.6.5.3 RESS retention :

RESS located inside the passenger compartment shall remain in the location in which they are installed and RESS components shall remain inside RESS boundaries. No part of any RESS that is located outside the passenger compartment for electric safety assessment shall enter the passenger compartment during or after the impact test.

The manufacturer shall demonstrate compliance in accordance with paragraph 46-1.7.7.

#### 46-1.7 Test Procedures for the protection of the occupants of vehicles operating on electrical power from high voltage and electrolyte spillage.

This paragraph describes test procedures to demonstrate compliance to the electrical safety requirements of paragraph 46-1.6.5. For example, megohmmeter or oscilloscope measurements are an appropriate alternative 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. Before the vehicle impact test conducted, the high voltage bus voltage ( $V_b$ ) (see figure 4) shall be measured and recorded to confirm that it is within the operating voltage of the vehicle as specified by the vehicle manufacturer.

#### 46-1.7.1 Test setup and equipment

If a high voltage disconnect function is used, measurements are to be taken from both 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 protected according to protection IPXXB following the impact test, measurements may only be taken between the device performing the disconnect function and the electrical loads.

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

#### 46-1.7.2 The following instructions may be used if voltage is measured.

After the impact test, determine the high voltage bus voltages ( $V_b$ ,  $V_1$ ,  $V_2$ ) (see figure 4).

The voltage measurement shall be made not earlier than 5 seconds, but, not later than 60 seconds after the impact.

This procedure is not applicable if the test is performed under the condition where the electric power train is not energized.

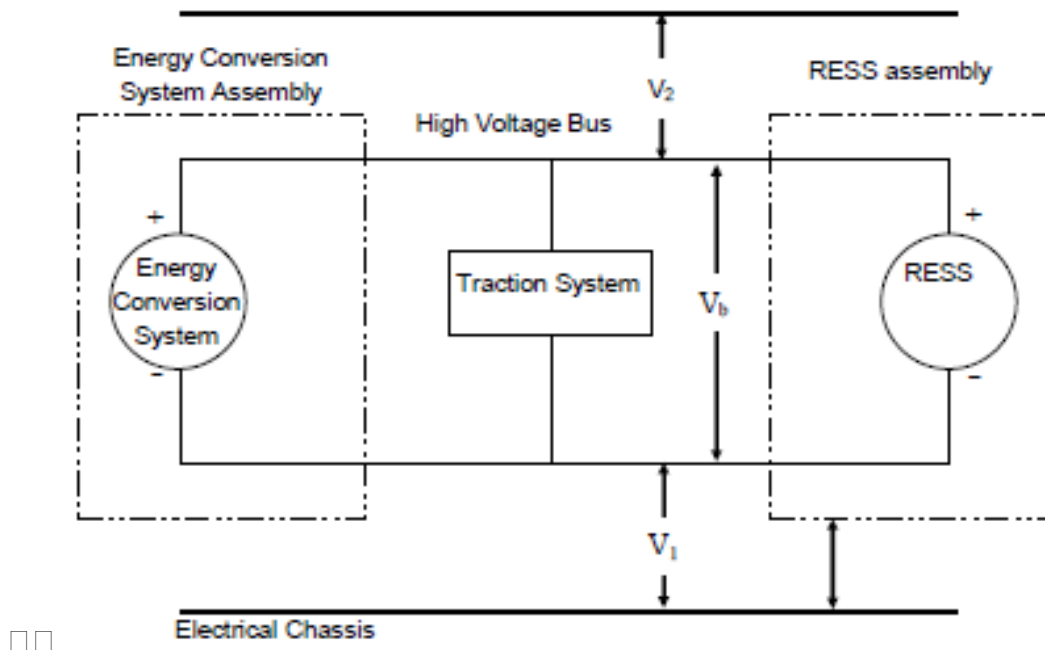


Fig 4 : Measurement of  $V_b$  、  $V_1$  、  $V_2$

#### 46-1.7.3 Assessment procedure for low electrical Energy :

Prior to the impact a switch S1 and a known discharge resistor  $R_e$  is connected in parallel to the relevant capacitance (ref. figure 5).

Not earlier than 5 seconds and not later than 60 seconds after the impact the switch S1 shall be closed while the voltage  $V_b$  and the current  $I_e$  are measured and recorded. The product of the voltage  $V_b$  and the current  $I_e$  shall be integrated over the period of time, starting from the moment when the switch S1 is closed ( $t_c$ ) until the voltage  $V_b$  falls below the high voltage threshold of 60 V DC ( $t_h$ ),. The resulting integration equals the total energy (TE) in joules.

$$(a) \quad TE = \int_{t_c}^{t_h} V_b \times I_e dt$$

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When  $V_b$  is measured at a point in time between 5 seconds and 60 seconds after the impact and the capacitance of the X-capacitors ( $C_x$ ) is specified by the manufacturer, total energy (TE) shall be calculated according to the following formula:

$$(b) TE = 0.5 \times C_x \times (V_b^2 - 3600)$$

When  $V_1$  and  $V_2$  (see figure 4) are measured at a point in time between 5 seconds and 60 seconds after the impact and the capacitances of the Y-capacitors ( $C_{y1}$ ,  $C_{y2}$ ) are specified by the manufacturer, total energy ( $TE_{y1}$ ,  $TE_{y2}$ ) shall be calculated according to the following formulas:

$$(c) TE_{y1} = 0.5 \times C_{y1} \times (V_1^2 - 3600)$$
$$TE_{y2} = 0.5 \times C_{y2} \times (V_2^2 - 3600)$$

This procedure is not applicable if the test is performed under the condition where the electric power train is not energized.

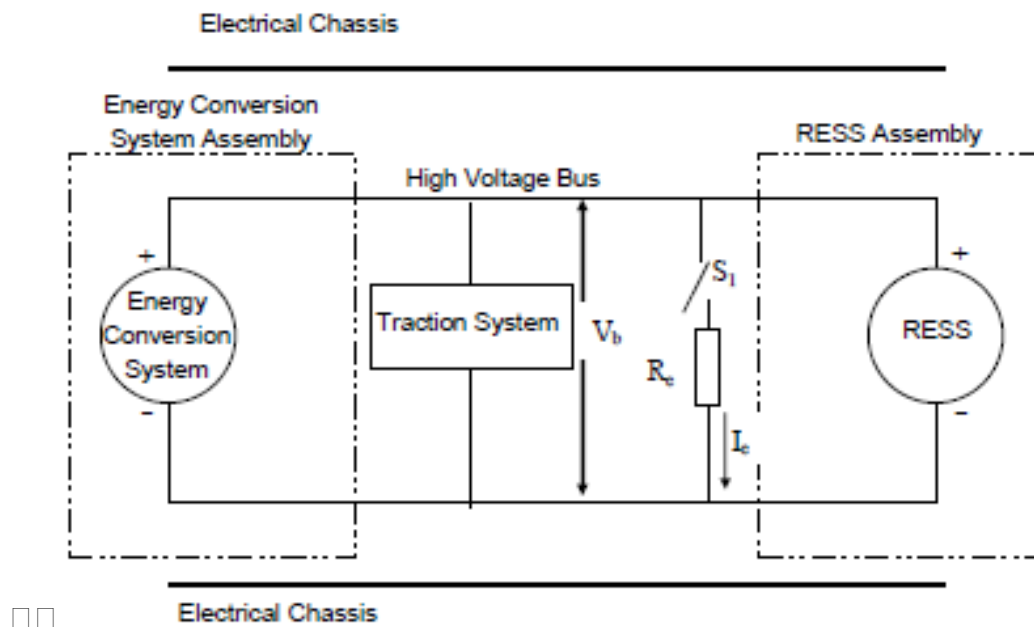


Fig 5 : measurement of high voltage bus energy stored in X-capacitors

#### 46-1.7.4 Physical Protection :

Following the vehicle impact test any parts surrounding the high voltage components shall be, without the use of tools, opened, disassembled or removed. All remaining surrounding parts shall be considered part of the physical protection.

The Jointed Test Finger described in figure 8 shall be inserted into any gaps or openings of the physical protection with a test force of  $10 \text{ N} \pm 10$  per cent for electrical safety assessment. If partial or full penetration into the physical protection by the Jointed Test Finger occurs, the Jointed Test Finger shall be placed in every position as specified below.

Starting from the straight position, both joints of the test finger shall be rotated progressively 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.

Internal electrical protection barriers are considered part of the enclosure.

If appropriate 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, between the Jointed Test Finger and high voltage live parts inside the electrical protection barrier or enclosure.

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#### 46-1.7.4.1. Acceptance conditions

The requirements of paragraph 46-1.6.5.1.3. shall be considered to be met if the Jointed Test Finger described in figure 8, is unable to contact high voltage live parts.

If necessary a mirror or a fiberscope may be used in order to inspect whether the Jointed Test Finger touches the high voltage buses.

If this requirement is verified by a signal circuit between the Jointed Test Finger and high voltage live parts, the lamp shall not light.

#### 46-1.7.5 Isolation resistance :

The isolation resistance between the high voltage bus and the electrical chassis may be demonstrated either by measurement or by a combination of measurement and calculation.

The following instructions should be used if the isolation resistance is demonstrated by measurement.

Measure and record the voltage ( $V_b$ ) between the negative and the positive side of the high voltage bus (see figure 4);

Measure and record the voltage ( $V_1$ ) between the negative side of the high voltage bus and the electrical chassis (see figure 4);

Measure and record the voltage ( $V_2$ ) between the positive side of the high voltage bus and the electrical chassis (see figure 4);

If  $V_1$  is greater than or equal to  $V_2$ , insert a standard known resistance ( $R_o$ ) between the negative side of the high voltage bus and the electrical chassis.

With  $R_o$  installed, measure the voltage ( $V_1'$ ) between the negative side of the high voltage bus and the vehicle electrical chassis (see figure 6).

Calculate the isolation resistance ( $R_i$ ) according to the formula shown below.

$$R_i = R_o \cdot (V_b / V_1' - V_b / V_1) \text{ or } R_i = R_o \cdot V_b \cdot (1 / V_1' - 1 / V_1)$$

Divide the result  $R_i$ , which is the electrical isolation resistance value in ohm( $\Omega$ ), by the working voltage of the high voltage bus in volt (V).

$$R_i (\Omega / V) = R_i (\Omega) / \text{Working voltage (V)}$$

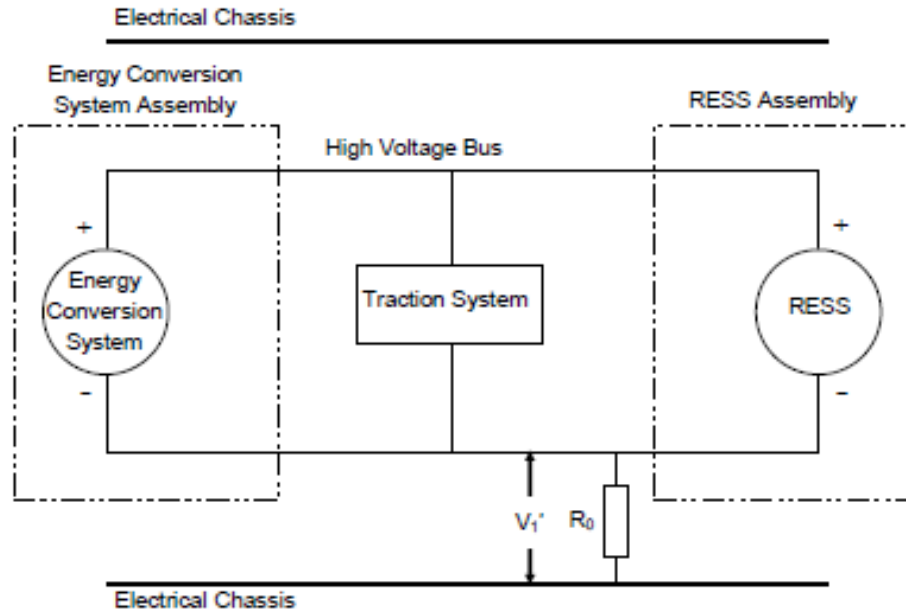


Fig 6 : Measurement of  $V_1'$

If  $V_2$  is greater than  $V_1$ , insert a standard known resistance ( $R_0$ ) between the positive side of the high voltage bus and the electrical chassis.

With  $R_0$  installed, measure the voltage ( $V_2'$ ) between the positive side of the high voltage bus and the electrical chassis (see figure 7).

Calculate the isolation resistance ( $R_i$ ) according to the formula shown below.

$$R_i = R_0 \cdot (V_b / V_2' - V_b / V_2) \text{ or } R_i = R_0 \cdot V_b \cdot (1/V_2' - 1/V_2)$$

Divide the result  $R_i$ , which is the electrical isolation resistance value in ohm( $\Omega$ ), by the working voltage of the high voltage bus in volt (V).

$$R_i (\Omega / V) = R_i (\Omega) / \text{Working voltage (V)}$$

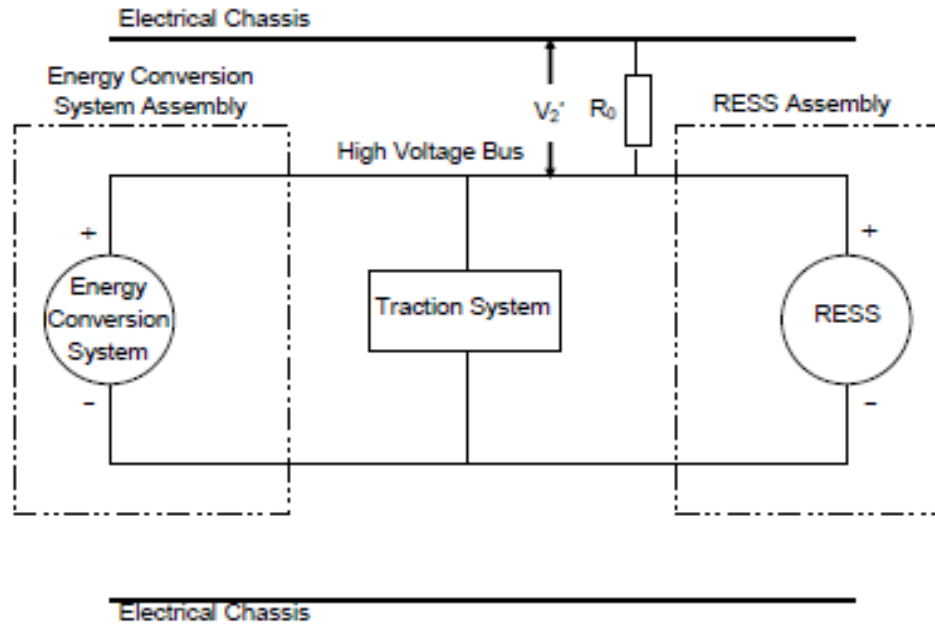


Fig 7 : Measurement of  $V_2'$

Note 1: The standard known resistance  $R_0$  (in  $\Omega$ ) should be the value of the minimum required isolation resistance ( $\Omega/V$ ) multiplied by the working voltage (V) of the vehicle plus/minus 20 per cent.  $R_0$  is not required to be precisely this value since the equations are valid for any  $R_0$ ; however, a  $R_0$  value in this range should provide a good resolution for the voltage measurements.

#### 46-1.7.6 Electrolyte spillage :

Appropriate coating shall be applied, if necessary, to the physical protection in order to confirm any electrolyte leakage from the RESS after the impact test.

Unless the manufacturer provides means to differentiate between the leakage of different liquids, all liquid leakage shall be considered as the electrolyte.

#### 46-1.7.7 RESS retention : Compliance shall be determined by visual inspection.



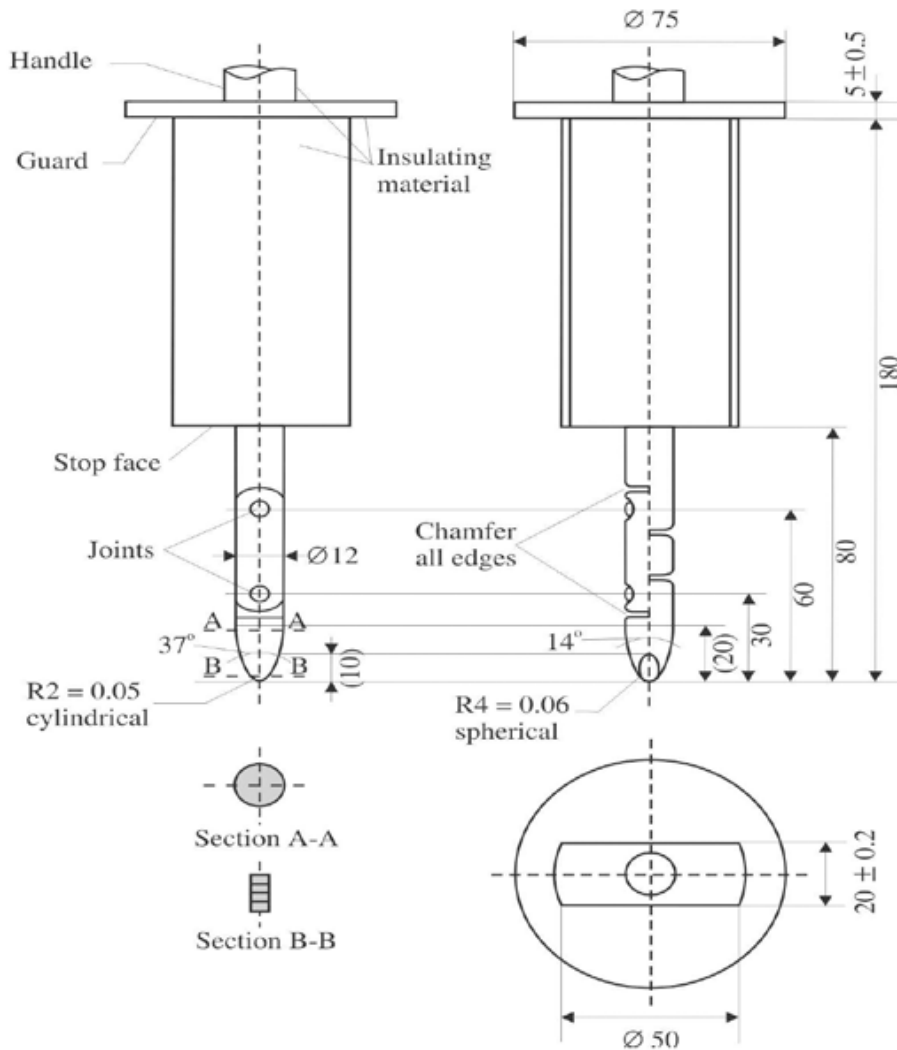


Fig 8 : Jointed test finger (IPXXB)

Material : metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

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(a) on angles:  $0/-10^{\circ}$

(b) on linear dimensions: up to 25 mm :  $0/-0.05$  mm over 25 mm:  $\pm 0.2$  mm

Both joints shall permit movement in the same plane and the same direction through an angle of  $90^{\circ}$  with a 0 to  $+10^{\circ}$  tolerance.