Remark: Pending at 4th ELSA (Paris)
Amendment at Ad-hoc(Paris)
Proposal from Japan

JAPAN Proposal

ELECTRICAL SAFETY PROVISIONS FOR VEHICLES Post Crash

1 General

~~*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.*~~

This module shall apply to safety requirements with respect to the electric power train of road vehicles equipped with one or more traction motor(s) operated by electric power and not permanently connected to the grid, as well as their high voltage components and systems which are galvanically connected to the high voltage bus of the electric power train. 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.

Note: Transposed from ECE R100 final draft and added the last sentence.

2 Definitions

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

2–1 **"Barrier"**

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

2-2 **"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

2–3 **"Direct contact"**

The contact of persons with live parts.

2–4 **"Electrical chassis"**

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

2–5 **"Electrical circuit"**

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

2-6 "**Electric energy conversion system"**

System that generates and provides electric energy for electric propulsion.

Note: Transposed from ECE R100 final draft.

2-7 **"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*~~

The electrical circuit which includes the traction motor(s), and may include the RESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the RESS.

Note: Transposed from ECE R100 final draft.

2-8 **"Electronic converter"**

~~*A device capable of controlling or converting electric power.*~~

A device capable of controlling and/or converting electric power for electric propulsion.

Note: Transposed from ECE R100 final draft.

2–9 **"Enclosure"**

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

[2–10 **"Exposed conductive part"**

~~*Conductive part which can be touched, and which only becomes electrically energized under failure conditions.]*~~

Conductive part which can be touched under the provisions of the protection degree IPXXB, and which becomes electrically energized under isolation-failure conditions.

Note: Transposed from ECE R100 final draft.

2-11 **"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.*~~

Classification of an electric component or circuit, if its working voltage is > 60 V and ≤ [1500] V direct current (DC) or > 30 V and ≤ [1000[V alternating current (AC) root mean square (rms).

Note: Transposed from ECE R100 final draft.

2-12 **"High Voltage Bus"**

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

2–13 **"Indirect contact"**

The contact of persons with exposed conductive parts.

2–14 **"Live parts"**

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

~~*2–15 **"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.*~~

Note: Deleted because this term is not used in this module.

2–15 **"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 high voltage live parts.

2–16 **"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), or a test wire (IPXXD) as defined in Attached Sheet 1

2-17 **"RESS"**

~~*Rechargeable energy storage system that provides the electric energy for propulsion*~~

Rechargeable energy storage system that provides electric energy for electric propulsion

Note: Transposed from ECE R100 final draft.

2–18 **"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.

Note: This term is used in Par. 5-5-1.

2–19 **"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.*~~

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.

Note: Transposed from ECE R100 final draft.

3 Requirements

During and after the specified crash test(s), vehicles shall meet the performance requirements specified in paragraphs 3.1 through 3.3.

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 30 minutes after a barrier impact test. Compliance may be demonstrated by test or analysis.]*~~

No hazardous content from propulsion batteries shall spill outside the RESS compartment within 30 minutes after a barrier impact test. Compliance may be demonstrated by test or analysis.

Comment: It is difficult to determine how much amount of the electrolyte is hazardous.
Concrete number is necessary. (5L?, 7%?)

3-2 [Traction battery 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, as determined by visual inspection.]*~~

RESS located inside the passenger compartment must remain in the installed location in which they are installed and RESS components shall remain inside RESS. No part of any RESS that is located outside the passenger compartment shall enter the passenger compartment during the test procedures, as determined by visual inspection.

Comment: Agree with the Ad-hoc proposal.

3-3 [Electrical Safety

~~*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.*~~

After each crash test, at least one of the following criteria specified in (a) thorough (d) shall be met. If the vehicle has an automatic disconnect function and it properly operates, the criteria shall apply to each divided portion individually.

(a) 3-3-1 and 3-3-4-1
(b) 3-3-2
(c) 3-3-3
(d) 3-3-4

Note: Protection against electrical shock cannot be ensured only by isolation resistance. Combination with the protection against direct contact with exposed (and not grounded) live parts is required.
Conform to the concept of the attachment 111.

~~*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.~~

3-3-1 Isolation Resistance

3-3-1-1 Electric power train consisting of separate DC- or AC-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 4 "Isolation Resistance Measurement Method".

Note: Transposed from ECE R100 final draft.

3-3-1-2 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.

Note: Transposed from ECE R100 final draft.

However, **if the protection degree IPXXB is satisfied for all AC high voltage buses after crash**, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100 Ω/volt of the working voltage.

Note: Modified the sentence of ECE R100 final draft.

The isolation resistance between the high voltage bus and the electrical chassis may be demonstrated by calculation, measurement or a combination of both.
The measurement shall be conducted according to Annex 4 "Isolation Resistance Measurement Method".

Note: Transposed from ECE R100 final draft.

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 Protection against direct contact

For protection of live parts, the protection degree IPXXB shall be provided.

3-3-4-2 Protection against indirect contact

For protection against indirect contact with live parts, all exposed conductive parts 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 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 Ω 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

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.*~~

4-2 Electric power train adjustments

4-2-1 The vehicle shall be in active driving possible mode, the high voltage system shall be energized.

Comment: It is unsafe in some cases.

Not all HEVs can be in active driving possible mode without engines running (farmable fuel is necessary for engines running.)

Also FCVs without batteries need hydrogen gas in their tanks.

At least some exemption is needed.

4-2-2 The RESS shall be at any state of charge which allows the normal operation of the power train recommended by the manufacturer.

Comment: Agree with Ad-hoc proposal. If (c) of the original statement is allowed, (a) and (b) do not make sense

4-2-1 Test Vehicle

The vehicle shall be in active driving possible mode, the high voltage system shall be energized.

However if the vehicle does not become in active driving possible mode without operating the internal combustion engine with flammable fuel or when the alternative gas or liquid is stored instead of hydrogen gas or liquid hydrogen for energy conversion system, the test shall be conducted according to an alternative test method specified in Annex XX.

Note: Added the exception for some HEVs and HFCVs.

Annex XX to be discussed.

4-2-2 RESS

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

Note: Transposed from Ad-hoc proposal.

~~*4-3 Energy conversion system*~~

~~*Proposal from OICA together with JAISIC*~~

4-2-3 Energy Conversion System that uses hydrogen gas as energy source

Hydrogen gas or liquid hydrogen shall be stored in the storage so that the energy conversion system is energized.

Alternative gas (i.e. helium gas) or alternative liquid (i.e. liquid nitrogen (LN2)) can be used instead of hydrogen gas or liquid hydrogen. However the requirement of 3-3-4 shall be satisfied for the power train component(s) to that is supplied the electric power by only the relevant energy conversion system after the crash, when this alternative is used.

Note: To be discussed.

5 Test Procedures

This section describes test procedures demonstrate compliance to the electrical safety requirements of paragraph 3-3. [Alternative test and analysis methods may also be used.] 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 after each of the specified crash tests.

5-1 Test setup and equipment

If a high voltage disconnect function is used, measurements of 5-3, 5-4 and 5-4 are 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 fully enclosed within a physical barrier or enclosure that maintains protection class IPXXB after crash test, measurements of 5-3, 5-4 and 5-4 may be taken only downstream 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 Ω.

5-2 Electrolyte spillage from RESS

Appropriate paint shall be applied, if necessary, to the barrier and enclosure in order to confirm the electrolyte is leaking from the RESS after the collision.

Add color to other liquid (such as coolant, oil, fuel, etc.), if necessary, so that the electrolyte and other liquid can be classified or separated.

If the electrolyte can not be clearly identified from the other leaking liquids, all liquid shall be considered as the electrolyte.

Note: Added the new description about the electrolyte leakage. (Maybe it should be specified in an Annex?)

5-3 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). 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). [If the RESS has exposed conductive parts, measure the voltage V3 between any exposed conductive parts of it and the electrical chassis.]*~~
~~*The measurement shall be made after [5 seconds of] the vehicle coming to rest after each crash test.*~~

~~*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). 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). [If the RESS has exposed conductive parts, measure the voltage V3 between any exposed conductive parts of it and the electrical chassis.]*~~
~~*The measurement shall be made after [5 seconds of] the vehicle coming to rest after each crash test.*~~

Comment: Even an OEM ensure that all exposed conductive parts are galvanically connected to the electrical chassis in pre-crash condition (this is the requirement of ECE R100), the certification body could not have confidence that this condition is maintained in post-crash. Therefore the measurement of V3 is necessary.
"After 5 seconds" is tricky. OEMs must assume that the measurement is conducted just after 5 seconds by certified body.
The requirement of "5 seconds" comes from SAE J1772. It seems to be too conservative. Although I have no good alternative idea, I think it should be discussed in ELSA.

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). 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). If the RESS has exposed conductive parts, measure the voltage V3 between any exposed conductive parts of it and the electrical chassis.
The measurement shall be made after [5 seconds of] the vehicle coming to rest after each crash test.

Note: Justification of "5 seconds" should be discussed again.

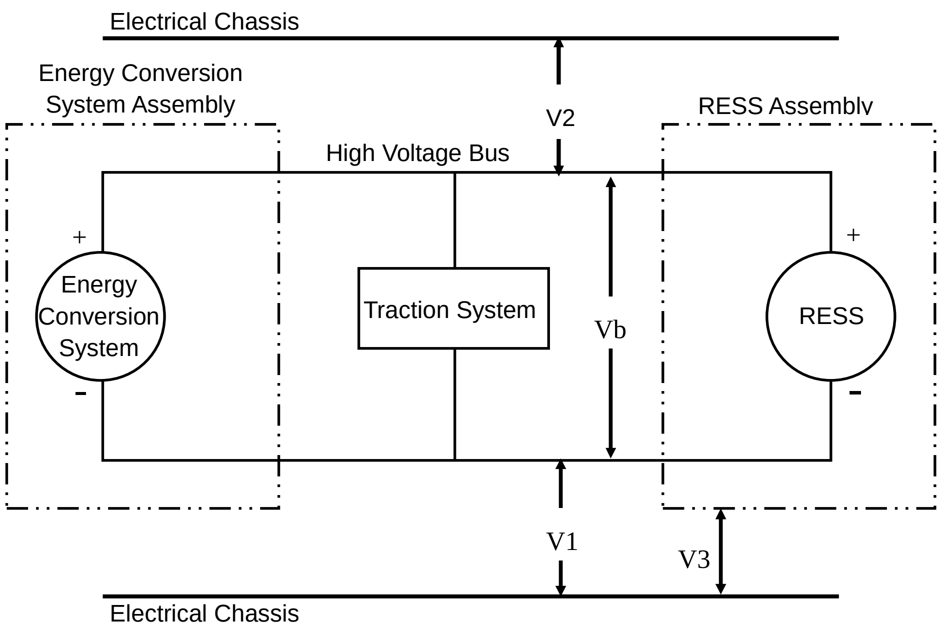


Figure 1~~2~~: Measurement of Vb, V1, V2

5-4 Electrical Resistance

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). 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 electrical chassis (see Figure 1):

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

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 vehicle electrical chassis (see Figure 2). Calculate the isolation resistance (Ri) according to the formula shown. Divide this electrical isolation resistance value (in Ω) by the working voltage of the high voltage bus (in volts).

$$Ri = Ro*(Vb/V1' - Vb/V1) \quad \text{or} \quad Ri = Ro*Vb*(1/V1' - 1/V1)$$

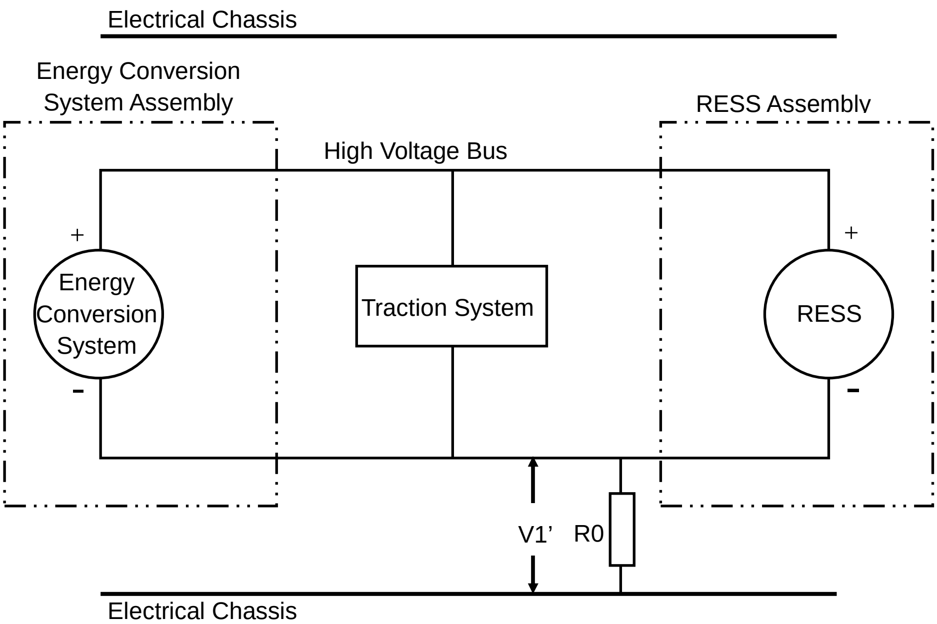
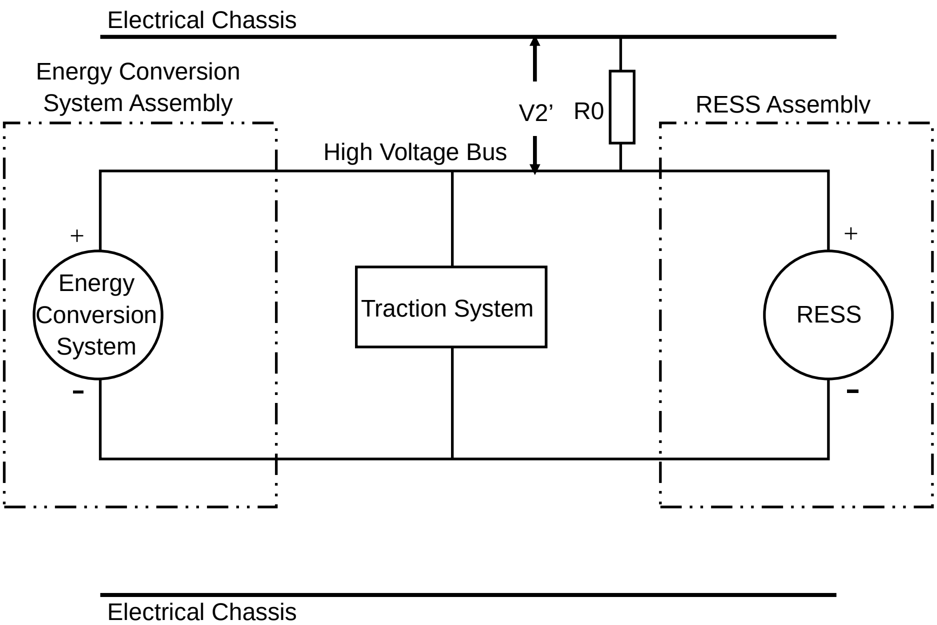


Figure 2~~3~~: Measurement of V1'

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

$$Ri = Ro*(Vb/V2' - Vb/V2) \quad \text{or} \quad Ri = Ro*Vb*(1/V2' - 1/V2)$$



NOTE 1: The standard known resistance Ro (in Ω) should be approximately 500 times the 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.

Comment: "Note" is not appropriate for regulations. Move to footnote?

5-5 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). 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.]

$$\int_{t_0}^{t_1} V_b \times I_e \, dt \qquad t_0 = ??? \quad t_1 = ???$$

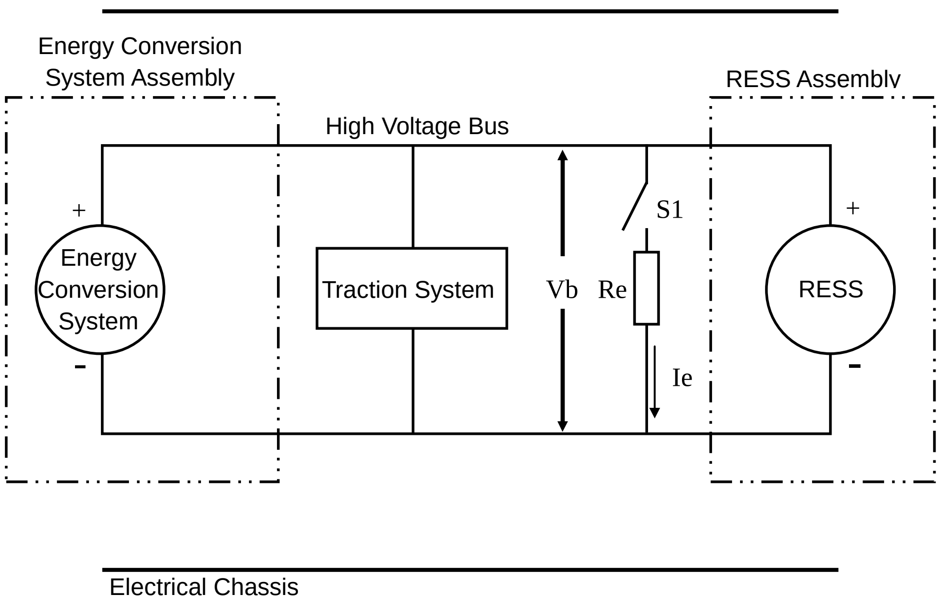


Figure 4: Measurement of high voltage bus energy

5-6 Physical Barrier

5-6-1 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 test force ~~*specified in*~~ of 10 N ± 10 % ~~*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.

5-6-2 Acceptance conditions

[The access probe shall not touch 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.

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.

ANNEX XX

ALTERNATIVE TEST METHOD WHEN VEHICLE DOES NOT BECOME ENERGIZED
- Without operating internal combustion engine with flammable fuel
- When alternative gas or liquid is stored instead of hydrogen gas or liquid hydrogen for energy conversion system

1 Test Conditions for Collision Test

1-1 Test vehicle

If the vehicle does not become in active driving possible mode without operating an internal combustion engine with flammable fuel or without supplying hydrogen gas or liquid hydrogen to energy conversion system, the test shall be conducted according to the alternative test method.

1-1-1 Automatic disconnect

In cases where the automatic disconnect is provided, the collision test shall be conducted with the automatic disconnect shuts off the traction battery. In this case, the alternative characteristic (such as airbag deployment signals) shall be confirmed to certify the automatic disconnect supposed to operate properly.

If the alternative characteristic is not confirmed, the measurement shall be conducted by assuming that the automatic disconnect doesn’t operate.

1-1-2 ……….