

National foreword

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Electrically propelled road vehicles — Safety specifications —

Part 4:

Post crash electrical safety

Véhicules routiers électriques — Spécifications de sécurité —

Partie 4: Exigences de sécurité électrique après accident



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

ISO 6469 consists of the following parts, under the general title *Electrically propelled road vehicles — Safety specifications*:

- *Part 1: On-board rechargeable energy storage system (RESS)*
- *Part 2: Vehicle operational safety means and protection against failures*
- *Part 3: Protection of persons against electric shock*
- *Part 4: Post crash electrical safety*

Electrically propelled road vehicles — Safety specifications —

Part 4: Post crash electrical safety

1 Scope

This part of ISO 6469 specifies safety requirements for the electric propulsion systems and conductively connected auxiliary electric systems of electrically propelled road vehicles for the protection of persons inside and outside the vehicle. It specifies electrical safety requirements for vehicle post-crash conditions.

It applies to electrically propelled road vehicles with voltage class B electric circuits.

It does not apply to motorcycles and mopeds.

It does not specify any crash test procedure. The safety requirements of this part of ISO 6469 apply to applicable vehicles in accordance with published crash test procedures of each country or region. Applicable vehicles are those vehicles which are explicitly specified in these crash test procedures.

It does not provide comprehensive safety information for first responders, emergency services, maintenance, and repair personnel.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons against electric shock*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

ISO/TR 8713, *Electrically propelled road vehicles — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 8713 and the following apply.

3.1

auxiliary electric system

on-board vehicle system, other than the propulsion system, which operates on electric energy

3.2

barrier

part providing protection against direct contact from any usual direction of access

3.3

conductive part

part capable of conducting electric current

3.4

direct contact

contact of persons with live parts

3.5

electric chassis

conductive parts of a vehicle that are electrically connected and whose potential is taken as reference

3.6

electric drive

combination of traction motor, power electronics, and their associated controls for the conversion of electric to mechanical power and vice versa

3.7

electric shock

physiological effect resulting from an electric current passing through a human body

3.8

electrically propelled vehicle

vehicle with at least one electric drive for vehicle propulsion

3.9

enclosure

part providing protection of equipment against direct contact from any direction

3.10

exposed conductive part

conductive part of the electric equipment, that can be touched by a test finger according to IPXXB (see ISO 20653) after removing barriers/enclosures that can be removed without using tools and that is not normally live, but which may become live under fault conditions

3.11

isolation resistance

resistance between live parts of voltage class B electric circuit and the electric chassis as well as the voltage class A system

3.12

line conductor

conductor which is electrically energized in normal operation and capable of contributing to the transmission or distribution of electric energy

3.13

live part

conductor or conductive part intended to be electrically energized in normal operation

3.14

maximum working voltage

highest value of a.c. voltage (rms) or of d.c. voltage which may occur in an electric system under any normal operating conditions according to manufacturer's specifications, disregarding transients

3.15

potential equalisation

electric connections of exposed conductive parts of the electric equipment to minimize differences in potential between these parts

3.16

rechargeable energy storage system

RESS

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

EXAMPLE Battery, capacitors.

3.17

voltage class A

classification of an electric component or circuit with a maximum working voltage of ≤ 30 V a.c. (rms) or ≤ 60 V d.c. respectively

3.18

voltage class B

classification of an electric component or circuit with a maximum working voltage of (>30 and $\leq 1\,000$) V a.c. (rms) or (>60 and $\leq 1\,500$) V d.c. respectively

3.19

X-capacitors

capacitors located between line conductors of different polarity

3.20

Y-capacitors

capacitors located between line conductor and electric chassis

4 Applied crash test procedures

The safety requirements of this part of ISO 6469 shall apply in accordance with the published crash test procedures of a country or region for vehicles or test configurations which are explicitly specified in these crash test procedures.

5 Electric safety requirements

5.1 General

The following requirements shall be fulfilled after a vehicle crash test or after a crash test with a test configuration according to 4.

NOTE Retention of voltage class B components, e.g. RESS, is not covered in this part of ISO 6469 because it is not relevant for electrical safety.

5.2 Protection against electric shock

5.2.1 General

After the crash test at least one of the criteria specified in [5.2.2](#) through [5.2.5](#) shall be met for each voltage class B electric circuit. This includes all voltage class B electric circuits which are disconnected or electrically separated in post-crash situations. For different parts of a circuit, different criteria specified in [5.2.2](#) through [5.2.5](#) may apply.

If the test is performed under the condition that part(s) of the voltage class B electric circuits are not electrically energized because of specific crash test conditions different from normal operation, the protection against electric shock shall be proved by either [5.2.3](#) or [5.2.4](#) for the relevant part(s). Examples for such specific test conditions are as follows:

- fuel cell vehicle crash test performed with alternative fuel;
- crash test performed with energy sources disconnected prior to the crash test.

NOTE Electronic switches can be used for disconnection.

5.2.2 Voltage limit

The voltages V_b , V_1 , and V_2 (see [Figure 1](#)) of the voltage class B electric circuits shall be equal to or less than 30 V a.c. (rms) or 60 V d.c. at a point in time t_m which is specified as

- either 10 s after the initial impact, if the vehicle comes to rest within 5 s after the initial impact, or
- 5 s after the vehicle comes to rest, if the vehicle does not come to rest within 5 s after the initial impact.

Compliance shall be tested in accordance with [7.2.2](#).

5.2.3 Isolation resistance

5.2.3.1 General

The isolation resistance shall fulfil the requirements according to [5.2.3.2](#) and [5.2.3.3](#).

If direct contact to one potential of the voltage class B electric circuit is possible, the energy in Y-capacitors, TE_y , as calculated in [7.2.5.2.2](#) shall be less than 0,2 J.

NOTE A potential body current caused by Y-capacitors is not limited by isolation resistance.

The isolation resistance criterion shall not apply if direct contact to more than one single potential of a part of the voltage class B electric circuit is possible; see [5.2.4](#) (physical protection). However, isolation resistance criterion is applicable if the voltage difference between those accessible live parts meets the voltage limit specified in [5.2.2](#) or the potential energy between them meets the energy limit specified in [5.2.5](#).

Compliance shall be tested in accordance with [7.2.3](#).

If test procedures include a static rollover test after a crash, evaluation of isolation resistance can be conducted before, during, and/or after the rollover test.

5.2.3.2 Separated d.c. and a.c. voltage class B electric circuits

If the a.c. voltage class B electric circuits and the d.c. voltage class B electric circuits are not conductively connected to each other, isolation resistance, divided by the maximum working voltage, shall have a minimum value of 100 Ω/V for d.c. circuits, and a minimum value of 500 Ω/V for a.c. circuits.

5.2.3.3 Combined d.c. and a.c. voltage class B electric circuits

If the a.c. voltage class B electric circuits and the d.c. voltage class B electric circuits are conductively connected, they shall meet one of the following requirements:

- a) isolation resistance, divided by the maximum working voltage, shall have a minimum value of 500 Ω/V ;
- b) isolation resistance, divided by the maximum working voltage, shall have a minimum value of 100 Ω/V and the a.c. circuit meets the physical protection as described in [5.2.4](#);
- c) isolation resistance, divided by the maximum working voltage, shall have a minimum value of 100 Ω/V and the a.c. circuit meets the voltage limit as described in [5.2.2](#);
- d) isolation resistance, divided by the maximum working voltage, shall have a minimum value of 100 Ω/V and the a.c. circuit meets the electrical energy limit as specified in [5.2.5](#).

5.2.4 Physical protection

For protection against direct contact with voltage class B live parts, the protection degree IPXXB in accordance with ISO 20653 shall be provided. Compliance shall be tested in accordance with [7.2.4.1](#).

In addition, one of the following requirements [a) or b)] shall be fulfilled:

- a) The potential equalisation paths intended by design shall be clarified in advance in accordance with the manufacturer's specification, e.g. using diagrams, etc. The potential equalisation paths intended by design are the relevant electric connections or potential equalisation in accordance with ISO 6469-3 for the vehicle as built. The resistance between all exposed conductive parts and the electric chassis shall be less than or equal to 0,1 Ω . This requirement is deemed to be satisfied if the connection is established and maintained by welding. Compliance shall be tested in accordance with [7.2.4.2](#).

In addition, one of the following requirements shall be fulfilled.

- A short circuit current, if any, shall be interrupted.
 - The isolation resistance divided by the maximum working voltage shall be $\geq 0,01 \Omega/V$ for d.c. circuits or $0,05 \Omega/V$ for a.c. circuits. This requirement is deemed to be satisfied if the system meets isolation requirements in [5.2.3](#). Compliance shall be tested in accordance with [7.2.4.3](#).
- b) At t_m (see [5.2.2](#)), the voltage between any two exposed conductive parts that can be touched simultaneously by a person shall be equal to or less than 30 V a.c. or 60 V d.c.. Compliance shall be tested in accordance with [7.2.4.4](#).

NOTE For overcurrent protection see [5.3](#).

If test procedures include a rollover test after crash, evaluation of physical protection shall be conducted after and might be additionally conducted before the rollover test.

5.2.5 Electrical energy limit

At t_m (see [5.2.2](#)), the total energy stored in X- and Y-capacitors shall meet the following requirement: $(TE_d + TE_{dyr})$, $(TE_d + TE_{yr})$, or $(TE_x + TE_y)$ shall be less than 0,2 J.

- TE_d is the measured electrical energy of X- and Y-capacitors (see [7.2.5.1.2](#)).
- TE_{dyr} is the measured remaining electrical energy of Y-capacitors (see [7.2.5.1.2](#)).
- TE_{yr} is the calculated remaining electrical energy in Y-capacitors (see [7.2.5.2.3](#)).
- TE_x is the calculated stored electrical energy in X-capacitors (see [7.2.5.2.1](#)).
- TE_y is the calculated stored electrical energy in Y-capacitors (see [7.2.5.2.2](#)).

NOTE The criterion of 0,2 J is based on IEC/TS 60479-1:2005, Figure 22 and considering capacitor discharge characteristics.

Compliance shall be tested in accordance with [7.2.5](#).

5.3 Protection against overcurrent

A potential overcurrent shall not lead to a hazardous situation after the crash test. This requirement is deemed to be satisfied if overcurrent protection is provided.

6 RESS electrolyte spillage

In the period from the impact until 30 min after the initial impact, no electrolyte from the RESS shall spill into the passenger compartment and not more than 5 l of electrolyte shall spill from the RESS outside of the passenger compartment.

Compliance shall be tested in accordance with [7.3](#).

If test procedures include a rollover test after crash, RESS electrolyte spillage during the rollover test shall also be included.

7 Testing

7.1 Test conditions

7.1.1 General

The environmental conditions during the test shall be according to the crash test procedures as defined in [Clause 4](#).

For the preparation of the vehicle or the test configuration (see [Clause 4](#)) the conditions specified in [7.1.2](#) shall apply.

7.1.2 Preparation of vehicle or test configuration

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

Prior to the vehicle crash test, the voltage class B electric circuit shall be electrically energized according to normal operating conditions. For exemptions, see [5.2.1](#).

If an automatic disconnect exists, the test can be performed with the automatic disconnect being opened before the crash test. In this case, the demonstration of the activation of the automatic disconnect might be required if [5.2.3](#) is applied to the electrical load, depending on the limit chosen for the isolation resistance. The demonstration shall include monitoring of automatic activation signal as well as the proper operation of the automatic disconnect under similar conditions according to the crash test.

Modifications necessary for the measurement can be carried out such as installation of measurement lines, disabling of isolation monitoring device, change of software, etc. These modifications shall not have significant influence on the results of the measurement.

The fuel supply system can be modified so that an appropriate amount of fuel can be used to run an internal combustion engine or a fuel cell system, to the extent permissible under the applicable crash test procedure.

NOTE The purpose to run the internal combustion engine or the fuel cell system is to electrically energize the voltage class B electric circuit.

7.2 Test procedures for electrical safety

7.2.1 Test setup and equipment

Before the vehicle crash test is conducted, the voltage class B electric circuit voltage, V_b (see [Figure 1](#)), shall be measured and recorded to confirm that it is within the operating voltage of the vehicle as specified by the vehicle manufacturer.

The measurement points of an electric circuit to be measured shall be clarified in advance, e.g. using electrical circuit diagrams, etc.

Measurements of voltage or energy or isolation resistance shall be taken on each disconnected or separated circuit, where applicable.

If the voltage class B disconnect device is integral to the RESS or the fuel cell system and the voltage class B electric circuit of the RESS or the fuel cell system fulfils physical protection according to [5.2.4](#) after the crash test, the measurements shall only be taken for the evaluation of the electrical loads.

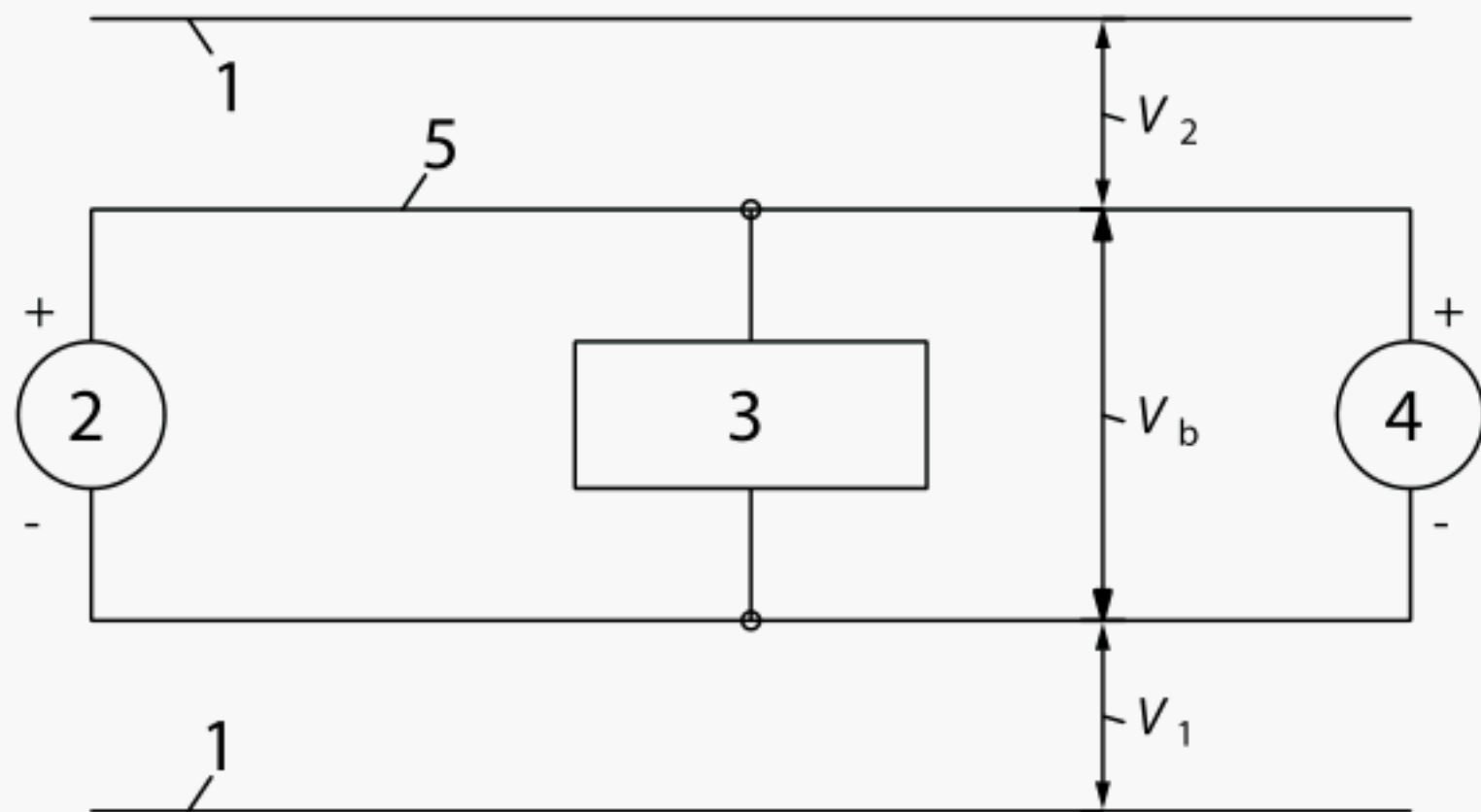
NOTE According to the circuit structure analysis, additional measurements at some places of the voltage class B electric circuit might be necessary. In this case, different criteria can be applied to different places.

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

7.2.2 Voltage limit

The voltages V_b , V_1 , and V_2 (see [Figure 1](#)) of the voltage class B electric circuit shall be measured after the crash test.

The voltage measurement shall be made at t_m (see [5.2.2](#)).



Key

- 1 electric chassis
- 2 fuel cell system
- 3 traction system or load
- 4 RESS
- 5 voltage class B electric circuit

Figure 1 — Measurement of V_b , V_1 , V_2

7.2.3 Isolation resistance

7.2.3.1 General

The isolation resistance measurement of the voltage class B d.c. circuits and a.c. circuits shall be conducted with an appropriate method selected by the vehicle manufacturer from those specified in [7.2.3.2](#) or [7.2.3.3](#).

The measurement shall be conducted within a period of 1 h after the initial impact maintaining the same conditions as in the crash test procedure.

NOTE The protection against electric shock is evaluated by the resistance value measured according to [7.2.3.2](#). The resistance value measured according to [7.2.3.3](#) is equal to or lower than that according to [7.2.3.2](#). Therefore, the resistance value according to [7.2.3.3](#) also can be used for the evaluation as it produces a conservative result.

7.2.3.2 Measurement using a d.c. voltage source connected to both terminals of the d.c. circuit

7.2.3.2.1 General

The voltage class B electric circuit shall be electrically energized by the vehicle’s own RESS or other voltage sources and the voltage shall be in the range of the working voltage during normal operation as specified by the vehicle manufacturer.

If the RESS or other voltage sources are automatically disconnected from the voltage class B electric circuit during crash test, it shall be reconnected for isolation measurement, or an external voltage source(s) shall be connected to the class B electric circuit. The external voltage source shall provide at least the same voltage level as the RESS or other voltage sources.

NOTE Examples for other voltage sources are fuel cell stack or generator.

7.2.3.2.2 Measurement procedure

The voltage, V_b , between the negative and the positive terminal of the voltage class B electric circuit (see [Figure 1](#)) shall be measured and recorded.

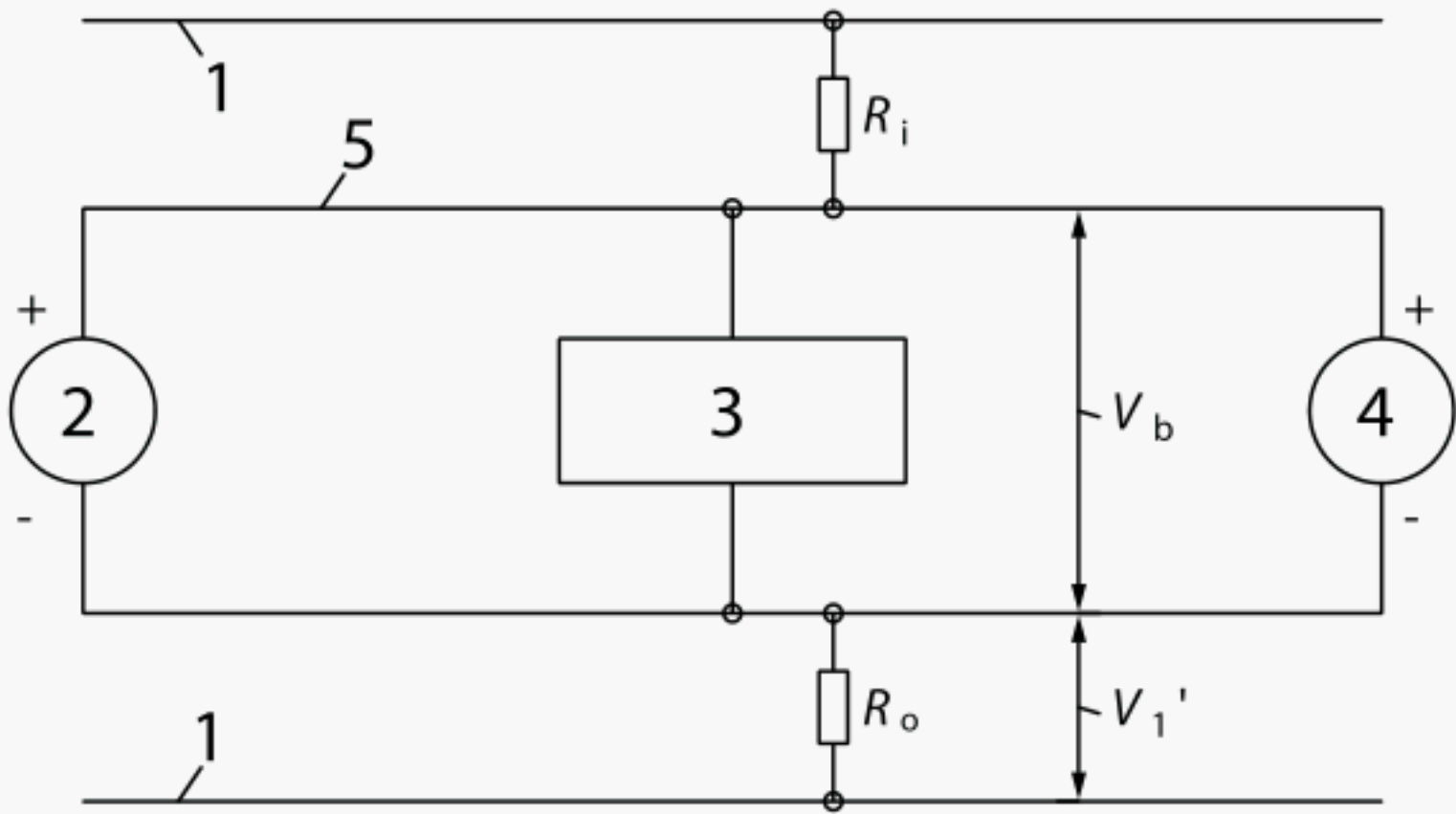
The voltage, V_1 , between the negative terminal of the voltage class B electric circuit and the electrical chassis (see [Figure 1](#)) shall be measured and recorded.

The voltage, V_2 , between the positive terminal of the voltage class B electric circuit and the electrical chassis (see [Figure 1](#)) shall be measured and recorded.

If V_1 is greater than or equal to V_2 , a resistor with a known resistance R_o shall be inserted between the negative terminal of the voltage class B electric circuit and the electrical chassis. With R_o installed, the voltage V_1' shall be measured between the negative terminal of the voltage class B electric circuit and the vehicle electrical chassis (see [Figure 2](#)). The isolation resistance R_i shall be calculated according to Formula (1):

$$R_i = R_o \times V_b \times (1/V_1' - 1/V_1)$$

(1)



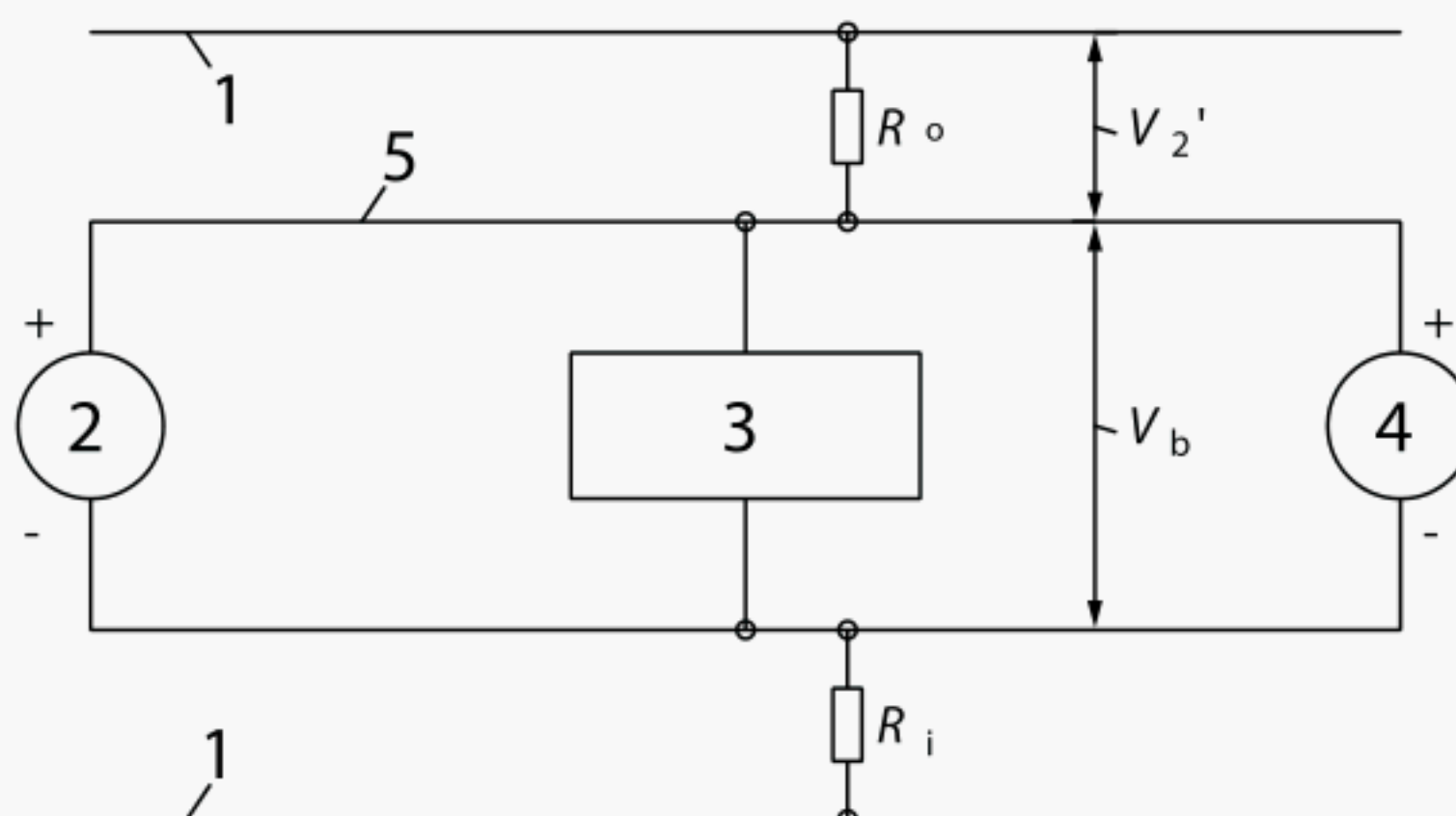
- Key
- 1 electrical chassis
 - 2 fuel cell system
 - 3 traction system or load
 - 4 RESS
 - 5 voltage class B electric circuit

Figure 2 — Measurement of V_1'

The result, R_i , which is the isolation resistance value (in Ω), shall be divided by the maximum working voltage, V_{be} , of the voltage class B electric circuit (in V) according to Formula (2):

$$r_i (\Omega / V) = R_i (\Omega) / V_{be} (V) \quad (2)$$

If V_2 is greater than V_1 , a resistor with known resistance, R_o , shall be inserted between the positive terminal of the voltage class B electric circuit and the electrical chassis. With R_o installed, the voltage, V_2' , shall be measured between the positive terminal of the voltage class B electric circuit and the electrical chassis (see [Figure 3](#)).



Key

- 1 electric chassis
- 2 fuel cell system
- 3 traction system or load
- 4 RESS
- 5 voltage class B electric circuit

Figure 3 — Measurement of V_2'

The isolation resistance, R_i , shall be calculated according to Formula (3):

$$R_i = R_o \times V_b \times (1/V_2' - 1/V_2) \quad (3)$$

The result, R_i , which is the isolation resistance value (in Ω), shall be divided by the maximum working voltage, V_{be} , of the voltage class B electric circuit (in V) according to Formula (4):

$$r_i (\Omega / V) = R_i (\Omega) / V_{be} (V) \quad (4)$$

NOTE The standard known resistance R_o (Ω) can be the value of the minimum required isolation resistance (in Ω / V) multiplied by the maximum working voltage of the voltage class B electric circuit ± 20 %. R_o is not required to be precisely this value since the equations are valid for any R_o ; however, a R_o value in this range provides an appropriate voltage range for the voltage measurements.

7.2.3.3 Measurement by applying a d.c. voltage between the voltage class B electric circuit and the electrical chassis

The test voltage shall be a d.c. voltage of at least the maximum working voltage of the voltage class B electric circuit and be applied between the live parts and the electric chassis for a time long enough to obtain stable reading.

If the system has live parts of several voltage ranges (e.g. because of boost converter), the isolation resistance shall be measured by applying the relevant maximum working voltage between the live parts of the relevant part of the circuit and the electric chassis.

An appropriate isolation resistance test instrument with a sufficient internal voltage source to provide the required test voltage shall be used.

The measured isolation resistance, R_i , shall be divided by the maximum working voltage, V_{be} , of the voltage class B electric circuit according to Formula (5):

$$r_i (\Omega / V) = R_i (\Omega) / V_{be} (V) \quad (5)$$

7.2.4 Physical protection

7.2.4.1 Protection against direct contact

7.2.4.1.1 Test procedure

Following the vehicle crash test, any parts surrounding the voltage class B components shall be opened, disassembled, or removed to the extent possible without the use of tools. All remaining surrounding parts shall be considered part of the physical protection.

The jointed test finger described in ISO 20653 shall be inserted into any gaps or openings of the physical protection with a test force of $10 \text{ N} \pm 10 \%$ 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° with respect to the axis of the adjoining section of the finger and shall be placed in every possible position.

If appropriate, a low-voltage supply (of not less than 40 V and not more than 50 V) in series with a suitable lamp can be connected between the jointed test finger and voltage class B live parts inside the electrical protection barrier or enclosure.

The measurement shall be conducted following the crash test procedure maintaining the same conditions as in the crash test procedure and movement of the vehicle shall be restricted to prevent changes of the mechanical state of the vehicle.

7.2.4.1.2 Acceptance conditions

The requirements in [5.2.4](#) shall be considered to be met if the jointed test finger described in ISO 20653 is unable to contact voltage class B live parts.

If necessary, a mirror or a fibrescope can be used in order to inspect whether the jointed test finger touches the voltage class B electric circuits.

If this requirement is verified by a signal circuit with a lamp between the jointed test finger and voltage class B live parts, the lamp shall not light.

7.2.4.2 Potential equalisation

For potential equalisation, one of the following procedures shall be applied as recommended by the vehicle manufacturer:

- visual inspection;
- measurement;

- combination of visual inspection and measurement.

For visual inspection, the following criteria shall be met.

- The cross sections of wired connections shall not be reduced by physical damage.
- The continuity of connection shall remain properly. No interruption shall occur.
- The connections shall remain properly fixed.

For the measurement, the following procedure shall apply.

The potential equalisation resistances shall be tested with a test current of at minimum 0,2 A and a voltage ≤ 60 V d.c., which shall be passed through the potential current path between exposed conductive parts and the vehicle electric chassis for at least 5 s. A lower test current and/or a shorter test time can be used, provided the accuracy of the potential equalisation resistance test results remain on a sufficient level.

7.2.4.3 Isolation resistance for physical protection

The test shall be performed with the RESS and other voltage class B sources disconnected. An appropriate resistance test instrument shall be used considering the isolation resistance limit values specified in 5.2.4. The measured resistance shall be divided by the maximum working voltage, V_{be} , of the voltage class B electric circuit.

7.2.4.4 Voltage limit for physical protection

The measurement shall be performed at t_m (see 5.2.2).

For compliance testing one of the following measurements or evaluations shall be performed.

- The voltage between any two reachable exposed conductive parts in a distance of 2,5 m shall be measured.
- The voltage between all relevant exposed conductive parts and electric chassis shall be measured. Only those exposed conductive parts are relevant that are located within a distance of 2,5 m to each other. After completing the voltage measurements, the voltage differences between these exposed conductive parts shall be calculated from the measurement results.

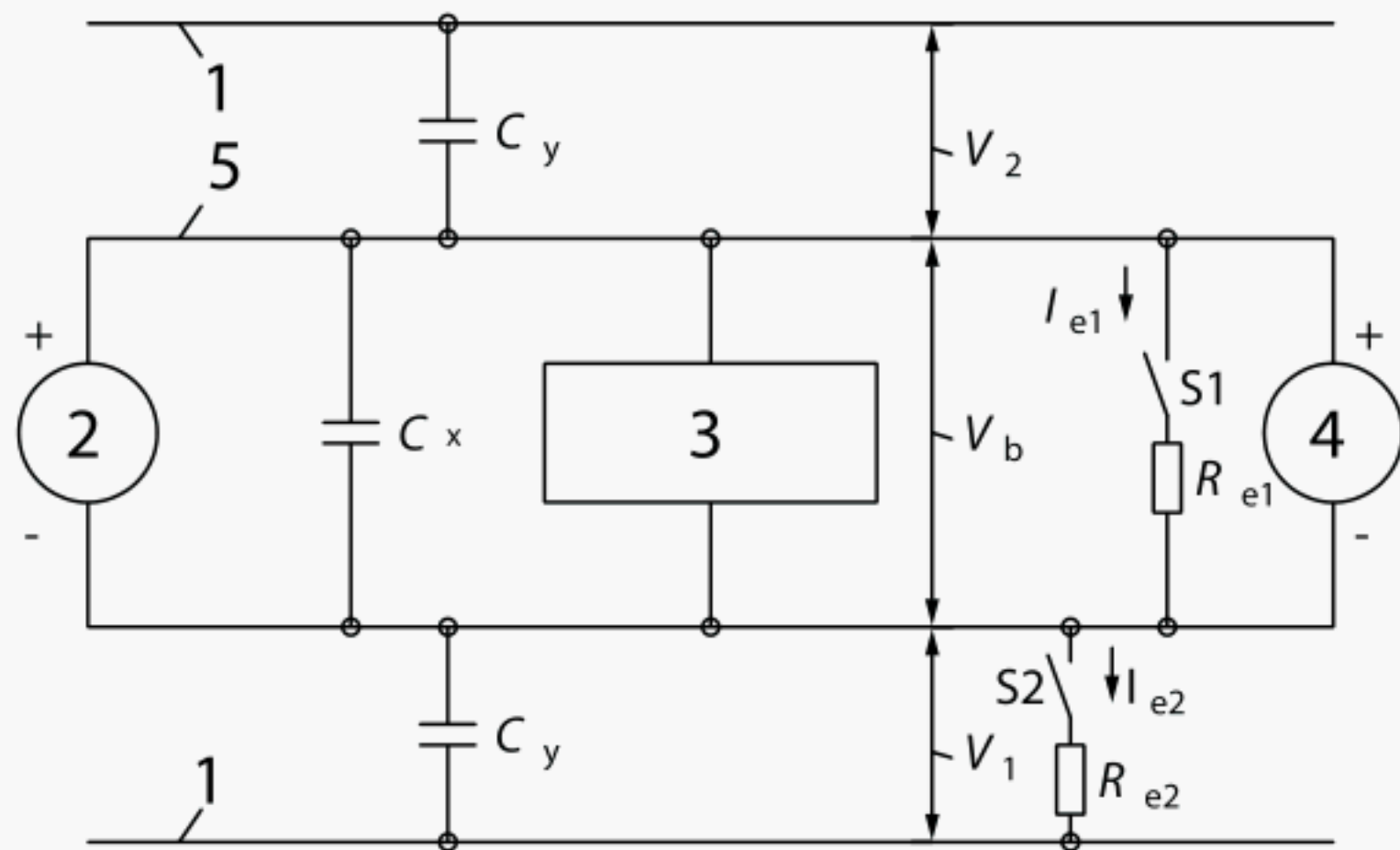
NOTE 2,5 m is the usual distance which a person can reach.

7.2.5 Electrical energy limit

7.2.5.1 Measurement of discharged electrical energy

7.2.5.1.1 General

Prior to the crash test, the switches S1 and S2 and the known discharge resistors R_{e1} and R_{e2} shall be installed in parallel to the relevant capacitances (see Figure 4).



- Key**
- 1 electric chassis
 - 2 fuel cell system
 - 3 traction system or load
 - 4 RESS
 - 5 voltage class B electric circuit

Figure 4 — Measurement of voltage class B electric circuit energy stored in capacitors (Example)

At t_m (see 5.2.2), the energy stored in X- and Y-capacitors shall be evaluated. For this evaluation, the stored energy shall be discharged by closing the switches S1 and S2 (see Figure 4) as described in the following clauses.

NOTE When TE_{yr} instead of TE_{dyr} is used for evaluation, S2 and R_{e2} are not necessary.

7.2.5.1.2 Measurement of discharged energy in X and Y-capacitors

The switches S1 and S2 shall be closed at a time to allow discharge of C_x and C_y within t_m (see 5.2.2) considering an interval for discharge of at least $3 \times (R_{e1} \times C_x)$ for C_x and $6 \times (R_{e2} \times C_y)$ for C_y . The voltage, V_b , and the current, I_{e1} , shall be measured and recorded. The current, I_{e1} , can be calculated from V_b and R_{e1} . The voltage V_1 and the current I_{e2} shall be measured and recorded. The current I_{e2} can be calculated from V_1 and R_{e2} .

The product of the voltage V_b and the current I_{e1} shall be integrated over a time interval of at least $3 \times (R_{e1} \times C_x)$ or $6 \times (R_{e2} \times C_y)$, whichever is higher, to obtain the discharged energy TE_d in Joule according to Formula (6):

$$TE_d = \int V_b \times I_{e1} dt \quad \text{or} \quad TE_d = \int V_b \times V_b / R_{e1} dt \tag{6}$$

The product of the voltage, V_1 , and the current, I_{e2} , shall be integrated over a time interval of at least $3 \times (R_{e1} \times C_x)$ or $6 \times (R_{e2} \times C_y)$, whichever is higher, to obtain the discharged energy (TE_{dyr}) in Joule according to Formula (7):

$$TE_{dyr} = \int V_1 \times I_{e2} dt \quad \text{or} \quad TE_{dyr} = \int V_1 \times V_1 / R_{e2} dt \tag{7}$$

7.2.5.2 Energy calculation

7.2.5.2.1 Energy calculation for X-capacitors

When V_b is measured at t_m (see 5.2.2) and the capacitance of the X-capacitors, C_x , is specified by the manufacturer, the energy in X-capacitors, TE_x , shall be calculated according to Formula (8):

$$TE_x = 0,5 \times C_x \times V_b^2 \quad (8)$$

Alternatively, TE can be calculated according to the Formula (9) using V_{be} , the maximum working voltage:

$$TE_x = 0,5 \times C_x \times V_{be}^2 \quad (9)$$

NOTE TE_x calculated using V_{be} represents the maximum possible energy value that can be stored in X-capacitors.

7.2.5.2.2 Energy calculation for Y-capacitors

When V_1 , V_2 (see Figure 4) are measured at t_m (see 5.2.2) and the capacitance per terminal C_y of the Y-capacitors is specified by the manufacturer, the energy in the Y-capacitors TE_y shall be calculated according to Formula (10):

$$TE_y = 0,5 \times C_y \times (V_1^2 + V_2^2) \quad (10)$$

Alternatively, TE_y can be calculated according to the Formula (11) using V_{be} , the maximum working voltage:

$$TE_y = 0,5 \times C_y \times V_{be}^2 \quad (11)$$

NOTE TE_y calculated using V_{be} represents the maximum possible energy value that can be stored in Y-capacitors.

7.2.5.2.3 Energy calculation for the remaining energy in Y-capacitors

After the discharge with S1 in 7.2.5.1.2 is completed, when V_1 and V_2 (see Figure 4) are measured at t_m (see 5.2.2) and the capacitances of the Y-capacitors C_y are specified by the manufacturer, the energy in the Y-capacitors (TE_{yr}) shall be calculated according to Formula (12):

$$TE_{yr} = 0,5 \times C_y \times (V_1^2 + V_2^2) \quad (12)$$

Alternatively, TE_{yr} can be calculated according to the Formula (13) using V_{be} , the maximum working voltage:

$$TE_{yr} = 0,5 \times C_y \times V_{be}^2 \quad (13)$$

NOTE TE_{yr} calculated using V_{be} represents the maximum possible energy value that can be stored in Y-capacitors.

7.3 Test procedure for RESS electrolyte spillage

Before and after the crash test, the vehicle shall be inspected for electrolyte spillage. Verification of electrolyte can be determined by visual inspection, litmus paper testing, and/or chemical analysis of the fluid.

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

8 Supplementary information

Special information for vehicle handling and electrical safety after an accident shall be provided for first responders and emergency services by appropriate documentation.

Special information for vehicle transport and further vehicle use after an accident shall be provided by appropriate documentation.

Special information on electrical safety for vehicle repair after an accident shall be provided by appropriate documentation.

Bibliography

[1] IEC/TS 60479-1: 2005, *Effects of current on human beings and livestock — Part 1: General aspects*

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