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Electrically propelled road vehicles — Safety specifications —

Part 3: Protection of persons against electric shock

Véhicules routiers électriques — Spécifications de sécurité —
Partie 3: Protection des personnes contre les chocs électriques

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6469-3 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

This second edition cancels and replaces the first edition (ISO 6469-3:2001), which has been technically revised. Technical Corrigendum ISO 6469-3:2001/Cor.1:2003 has been incorporated.

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*

Electrically propelled road vehicles — Safety specifications —

Part 3:
Protection of persons against electric shock

IMPORTANT — The electronic file of this document contains colors which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a color printer.

1 Scope

This part of ISO 6469 specifies requirements for the electric propulsion systems and conductively connected auxiliary electric systems, if any, of electrically propelled road vehicles for the protection of persons inside and outside the vehicle against electric shock.

It does not apply to motorcycles and vehicles not primarily intended as road vehicles, such as material handling trucks or forklifts.

It applies only to on-board electric circuits with maximum working voltages according to voltage class B.

It does not provide comprehensive safety information for manufacturing, maintenance and repair personnel.

NOTE Requirements for the electric power supply interface conductively connected to the external power supply (grid) for charging the RESS are also specified in IEC 61851-1 and IEC 61851-21.

2 Normative references

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

ISO 6469-1, *Electrically propelled road vehicles — Safety specifications — Part 1: On-board rechargeable energy storage system (RESS)*

ISO 7010, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

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

IEC 60664 (all parts), *Insulation coordination for equipment within low-voltage systems*

3 Terms and definitions

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

3.1
auxiliary electric system
on-board vehicle system, other than the propulsion system, that operates on electric energy

3.2
balance of electric power system
remaining portion of a **voltage class B** (3.31) electric circuit when all RESS and **fuel cell stacks** (3.18) are disconnected

3.3
barrier
part providing protection against direct contact from any usual direction of access

3.4
basic insulation
insulation applied to **live parts** (3.22) for protection against **direct contact** (3.10)

NOTE Basic insulation does not necessarily include isolations used exclusively for functional purposes.

3.5
basic protection
protection against **direct contact** (3.10) with **live parts** (3.22) under fault-free conditions

3.6
battery pack
mechanical assembly comprising battery cells and retaining frames or trays, and possibly components for battery management

3.7
clearance
shortest distance in air between **conductive parts** (3.8)

3.8
conductive part
part capable of conducting electric current

3.9
creepage distance
shortest distance along the surface of a solid insulating material between two **conductive parts** (3.8)

3.10
direct contact
contact of persons with **live parts** (3.22)

3.11
double insulation
insulation system comprising both **basic insulation** (3.4) and **supplementary insulation** (3.28)

3.12
electric chassis
conductive parts (3.8) of a vehicle that are electrically connected and whose potential is taken as reference

3.13
electric shock
physiological effect resulting from an electric current passing through a human body

3.14
electrically propelled vehicle
vehicle with one or more **electric drive**(s) (3.15) for vehicle propulsion

3.15
electric drive
combination of traction motor, power electronics and their associated controls for the conversion of electric to mechanical power and vice versa

3.16
enclosure
part providing protection of equipment against **direct contact** (3.10) from any direction

3.17
exposed conductive part
conductive part (3.8) 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 can become live under fault conditions

3.18
fuel cell stack
assembly of two or more fuel cells that are electrically connected

3.19
fuel cell system
system, typically containing the following subsystems: **fuel cell stack** (3.18), air processing, fuel processing, thermal management, water management, and their control

3.20
isolation resistance
resistance between live parts of **voltage class B** (3.31) electric circuit and the **electric chassis** (3.12) as well as the **voltage class A** (3.30) system

3.21
isolation resistance monitoring system
system that periodically or continuously monitors the **isolation resistance** (3.20) between **live parts** (3.22) and the **electric chassis** (3.12)

3.22
live part
conductor or **conductive part** (3.8) intended to be electrically energized in normal use

3.23
maximum working voltage
highest value of a.c. voltage (rms) or of d.c. voltage that can occur in an electric system under any normal operating conditions according to the manufacturer's specifications, disregarding transients

3.24
potential equalization
electric connections of exposed **conductive parts** (3.8) of the electric equipment to minimize differences in potential between these parts

3.25
protection degree
protection provided by a **barrier** (3.3)/**enclosure** (3.16) related to the contact with **live parts** (3.22) by a test probe, such as a test finger (IPXXB), a test rod (IPXXC), or a test wire (IPXXD) in accordance with ISO 20653

3.26
rechargeable energy storage system
RESS
system that stores energy for delivery of electric energy and that is rechargeable

EXAMPLES Batteries, capacitors.

3.27
reinforced insulation
insulation of **live parts** (3.22) for protection against **electric shock** (3.13) equivalent to **double insulation** (3.11)

NOTE Reinforced insulation does not imply that the insulation shall be a homogeneous piece. The reinforced insulation may be composed of several layers that cannot be tested individually as supplementary or basic insulation.

3.28
supplementary insulation
independent insulation applied in addition to **basic insulation** (3.4) for protection against **electric shock** (3.13) in the event of a failure of the **basic insulation** (3.4)

3.29
traction battery
collection of all **battery packs** (3.6) that are electrically connected, for the supply of electric power to the **electric drive** (3.15) and to the conductively connected auxiliary electric system**,** if any

3.30
voltage class A
classification of an electric component or circuit with a maximum working voltage of less than 30 V a.c. (rms) or 60 V d.c.

NOTE For more details see Clause 5.

3.31
voltage class B
classification of an electric component or circuit with a maximum working voltage between 30 V a.c. (rms) and 1 000 V a.c. (rms) or between 60 V d.c. and 1 500 V d.c.

4 Environmental and operational conditions

The requirements given in this part of ISO 6469 shall be met across the range of environmental and operational conditions for which the electrically propelled vehicle is designed to operate, as specified by the vehicle manufacturer.

NOTE See ISO 16750 for guidance.

5 Voltage classes

Depending on its maximum working voltage, U, an electric component or circuit belongs to one of the voltage classes specified in Table 1.

Table 1 — Voltage classes

Voltage class	Maximum working voltage	
	d.c. V	a.c. V (rms value)
A	$0 < U \leq 60$	$0 < U \leq 30$
B	$60 < U \leq 1\,500$	$30 < U \leq 1\,000$

NOTE The values 60 V d.c./30 V a.c. (rms) are selected taking into account humid weather conditions.

6 Marking

6.1 Marking of voltage class B electric components

The symbol W 012 in accordance with ISO 7010 shown in Figure 1 shall appear on (preferably) or near voltage class B electric power sources as RESS and fuel cell stacks.

The same symbol shall be visible on barriers and enclosures, which, when removed, expose live parts of voltage class B electric circuits. Accessibility and removability of barriers/enclosures should be considered when evaluating the requirement for the symbol.

Figure 1 — Marking of voltage class B electric components

6.2 Marking of voltage class B wiring

The outer covering of cables and harness for voltage class B electric circuits not within enclosures or behind barriers shall be marked with orange color.

Voltage class B connectors may be identified by the harnesses to which the connector is attached.

NOTE Specifications of the orange color are given e.g. in standards in the US (8.75R5.75/12.5) and in Japan (8.8R5.8/12.5) according to the Munsell color system.

7 Measures and requirements for protection of persons against electric shock

7.1 General

Protection against electric shock shall be composed of

— basic protection measures against direct contact with live parts;

— measures for protection under single-failure conditions.

The protection measures shall meet the requirements as described in 7.2 and 7.3 and compliance shall be tested in accordance with the test methods specified in Clause 8.

7.2 Basic protection measures

Persons shall be protected against direct contact with the live parts of the voltage class B electric circuits.

The protection measures against direct contact shall be provided by either one or both of the following:

— basic insulation of the live parts;

— barriers/enclosures, preventing access to the live parts.

The barriers/enclosures may be electrically conductive or non-conductive.

7.3 Protection under single-failure conditions

7.3.1 Potential equalization

As a general rule, exposed conductive parts of voltage class B electric equipment, including exposed conductive barriers/enclosures, shall be bonded to the electric chassis for potential equalization in accordance with the requirements in 7.9.

7.3.2 Isolation resistance

The voltage class B electric circuits intended to be not conductively connected to the grid shall have sufficient isolation resistance in accordance with the requirements in 7.7.

If the minimum isolation resistance requirement of such circuits cannot be maintained under all operational conditions and over the entire service life, one of the following measures shall be applied:

— monitoring of the isolation resistance periodically or continuously; an appropriate warning shall be provided if loss of isolation resistance is detected; the voltage class B system may be deactivated depending on the operational state of the vehicle or the ability to activate the voltage class B system may be limited;

— double or reinforced insulation instead of basic insulation;

— one or more layers of insulation, barriers and/or enclosures in addition to the basic protection;

— rigid barriers/enclosures with sufficient mechanical robustness and durability, over the vehicle service life.

Requirements on isolation resistance for voltage class B electric circuits intended to be conductively connected to the grid are given in 7.10.2.

NOTE 1 Isolation resistances below the required minimum values can occur due to deterioration of fuel cell (FC) systems' cooling liquids or of certain battery types.

NOTE 2 Coordination between multiple isolation monitoring systems can be necessary, e.g. during charging.

NOTE 3 The isolation resistance is approximately zero for a voltage class B electric circuit conductively connected to the grid.

NOTE 4 Additional layer(s) of insulation and double or reinforced insulation include, but are not limited to, those for voltage class B wiring.

NOTE 5 The rigid barriers/enclosures include, but are not limited to, power control enclosures, motor housings, connector casings and housings, etc. They can be used as single measure instead of basic barriers/enclosures to meet both basic and single-failure protection requirements.

7.3.3 Capacitive couplings

7.3.3.1 Capacitive couplings between a voltage class B potential and electric chassis usually result from Y capacitors, used for electromagnetic compatibility (EMC) reasons, or parasitic capacitive couplings.

7.3.3.2 For d.c. body currents caused by discharge of such capacitive couplings when touching d.c. class B voltage, one of the following options shall be fulfilled:

— energy of the total capacitance between any energized voltage class B live part and the electric chassis shall be $<0{,}2$ J at its maximum working voltage; total capacitance should be calculated based on designed values of related parts and components;

— alternative mechanical or electrical measures for d.c. voltage class B electric circuits; see 7.3.3.4.

7.3.3.3 For a.c. body currents caused by such capacitive couplings when touching a.c. class B voltage one of the following options shall be fulfilled:

- a.c. body current shall not exceed 5 mA when measured in accordance with IEC 60950-1;
- alternative mechanical or electrical measures for a.c. voltage class B electric circuits; see 7.3.3.4.

7.3.3.4 Alternative electrical or mechanical measures include the following:

- double or reinforced insulation instead of basic insulation;
- one or more layers of insulation, barriers and/or enclosures in addition to the basic protection;
- rigid barriers/enclosures with sufficient mechanical robustness and durability, over the vehicle service life.

7.3.4 De-energization

The voltage class B electric circuit in question may be de-energized as a protection measure. The monitoring of faults within the circuit or the detection of events may be used to trigger the de-energization. One of the following conditions shall be met for the de-energized circuit.

- The voltage shall be reduced to less than 30 V a.c. (rms) for a.c. circuits and 60 V d.c. for d.c. circuits.
- The total stored energy of the circuit shall be <0,2 J.

The transition time to reach the de-energized state shall be specified by the manufacturer in accordance with expected failures and operating conditions.

7.4 Alternative approach for protection against electric shock

As an alternative to 7.3, the vehicle manufacturer shall conduct an appropriate hazard analysis and establish a set of measures which give sufficient protection against electric shock under single-failure conditions.

7.5 Requirements for insulation

If protection is provided by insulation, the live parts of the electric system shall be totally encapsulated by insulation that can be removed only by destruction.

The insulating material shall be suitable to the maximum working voltage and temperature ratings of the vehicle and its systems (see also Clause 4).

The insulation shall have sufficient capability to withstand the usual voltage. Compliance shall be tested in accordance with 8.3.

7.6 Requirements for barriers/enclosures

7.6.1 General

If protection is provided by barriers/enclosures, live parts shall be placed inside enclosures or behind barriers, preventing access to the live parts from any usual direction of access.

The barriers/enclosures shall provide sufficient mechanical resistance under normal operating conditions, as specified by the manufacturer.

If barriers/enclosures are accessible directly, they shall be opened or removed only by use of tools or maintenance keys or they shall have means to deactivate live parts with class B voltage, e.g. an interlock.

See 6.1 for marking of barriers/enclosures.

