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Electrically propelled road vehicles — Safety specifications —

Part 1: Rechargeable energy storage system (RESS)

Véhicules routiers électriques — Spécifications de sécurité —
Partie 1: Système de stockage d'énergie rechargeable (RESS)

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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. www.iso.org/directives

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

This third edition cancels and replaces the second edition (ISO 6469-1:2009) and ISO 12405-3:2014, which have been technically revised.

The main changes compared to ISO 6469-1:2009 and ISO 12405-3:2014 are as follows:

— test descriptions and requirements were reworked to include specific characteristics for lithium-ion based battery systems;

— document was reworked to become a general safety standard for all RESS types; and

— almost all test procedures and descriptions as given in the previous versions of both documents have been adapted to the latest technical developments.

A list of all parts in the ISO 6469 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Electrically propelled road vehicles — Safety specifications —

Part 1:
Rechargeable energy storage system (RESS)

1 Scope

This document specifies safety requirements for rechargeable energy storage systems (RESS) of electrically propelled road vehicles for the protection of persons.

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

NOTE 1 Requirements for motorcycles and mopeds are specified in ISO 13063 and ISO 18243.

NOTE 2 Additional safety requirements can apply for RESS that can be recharged by means different from supplying electric energy (e.g. redox flow battery).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety*

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

IEC 60068-2-27, *Environmental testing - Part 2-27: Tests — Test Ea and guidance: Shock*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
bus
<vehicle type> vehicle designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 t

3.2
capacity
total number of ampere-hours that can be withdrawn from a fully charged *RESS* (3.22) under specified operating

3.3
clearance
shortest distance in air between two *conductive parts* (3.4)

[SOURCE: IEC 60664-1:2007, 3.2]

3.4
conductive part
part which can carry electric current

[SOURCE: IEC 60050-195:1998, 195-01-06]

3.5
creepage distance
shortest distance along a surface of a solid insulating material between two *conductive parts* (3.4)

[SOURCE: IEC 60050-151:2001/AMD1:2013, 151-15-50]

3.6
customer
party that is interested in using the *RESS* (3.22) or *RESS subsystem* (3.24) and therefore, orders or performs the test

EXAMPLE Vehicle manufacturers.

[SOURCE: ISO PAS 19295:2016, modified — "voltage class B component or system" replaced by "RESS or RESS subsystems and therefore, orders or performs the test", EXAMPLE added]

3.7
electric chassis
conductive parts (3.4) of a vehicle that are electrically connected and whose potential is taken as reference

[SOURCE: ISO 6469-3:2018, 3.12]

3.8
electric drive
combination of an electric traction motor, power electronics and their associated controls for the conversion of electric to mechanical power and vice versa

[SOURCE: ISO 6469-3:2018, 3.13]

3.9
electrically propelled vehicle
vehicle with one or more *electric drive(s)* (3.8) for vehicle propulsion

[SOURCE: ISO 6469-3:2018, 3.15]

3.10
explosion
sudden release of energy sufficient to cause pressure waves and/or projectiles that can cause structural and/or physical damage to the surrounding area

3.11
flammable electrolyte
electrolyte having a flash point of not more than 93 °C

Note 1 to entry: The determination of flash point is based on ISO 2592.

3.12
heavy-duty truck
vehicle designed and constructed for the carriage of goods and having a maximum mass exceeding 12 t

3.13
isolation resistance
insulation resistance
resistance between *live parts* (3.16) of an electric circuit and the *electric chassis* (3.7) as well as other electric circuits which are insulated from this electric circuit

[SOURCE: ISO 6469-3:2018, 3.23]

3.14
isolation resistance monitoring system
system that periodically or continuously monitors the *isolation resistance* (3.13) between *live parts* (3.16) and the *electric chassis* (3.7)

[SOURCE: ISO 6469-3:2018, 3.24]

3.15
leakage
escape of liquid or gas except for *venting* (3.28)

3.16
live part
conductor or *conductive part* (3.4) intended to be energized in normal use, but by convention, not the *electric chassis* (3.7)

[SOURCE: IEC 60050-195:1998, 195-02-19, modified — "including a neutral conductor" and Note 1 to entry deleted and "a PEN conductor or PEM conductor or PEL conductor" replaced by "the electric chassis"]

3.17
maximum operating temperature
highest value of the temperature at which the systems/components can be operated continuously

3.18
maximum working voltage
highest value of AC voltage (rms) or of DC voltage that can occur under any normal operating conditions according to the manufacturer's specifications, disregarding transients and ripple

[SOURCE: ISO 6469-3:2018, 3.26]

3.19
medium-duty truck
vehicle designed and constructed for the carriage of goods and having a maximum mass exceeding 3,5 t but not exceeding 12 t

3.20
midi bus
vehicle designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 t

3.21
overcurrent protection
protection intended to operate when the current is in excess of a predetermined value

[SOURCE: IEC 60050-195:1998, 448-14-26]

3.22
rechargeable energy storage system
RESS
rechargeable system that stores energy for delivery of electric energy for the *electric drive* (3.8)

EXAMPLE Battery, capacitor, flywheel.

3.23
RESS control unit
electronic device that controls functions of the *RESS* (3.22) and that provides communication between the *RESS* (3.22) and other vehicle controllers

EXAMPLE Battery control unit.

3.24
RESS subsystem
any assembly of *RESS* (3.22) components which stores energy

3.25
rupture
loss of mechanical integrity of an enclosure resulting in openings not fulfilling protection degree IPXXB according to ISO 20653

Note 1 to entry: Predetermined openings for venting are not considered as rupture.

3.26
state of charge
SOC
available *capacity* (3.2) of an *RESS* (3.22) or *RESS subsystem* (3.24) expressed as a percentage of rated *capacity* (3.2)

3.27
supplier
party that provides *RESS* (3.22) or *RESS subsystem* (3.24)

EXAMPLE RESS manufacturers.

[SOURCE: ISO PAS 19295:2016, modified — "voltage class B component or system" replaced by "RESS or RESS subsystems", EXAMPLE added]

3.28
venting
release of excessive pressure intended by design

3.29
voltage class
classification of an electric component or circuit according to its *maximum working voltage* (3.18)

Note 1 to entry: The classification to the voltage classes A, B and B2 is according to ISO 6469-3:2018

[SOURCE: ISO 6469-3:2018, 3.35, modified — Note 1 to entry added.]

3.30
water depth
w
water depth level a vehicle is designed for operation according to the vehicle manufacturer's specification

Note 1 to entry: The vehicle manufacturer may consider the local environmental conditions where the vehicle is placed on the market.

4 General requirements

4.1 General electrical requirements

If not otherwise specified in this document, the voltage class B RESS shall fulfil the electrical safety requirements in accordance with ISO 6469-3. These electrical safety requirements may be fulfilled for an RESS on the component or vehicle level.

The voltage class B RESS or the voltage class B RESS subsystem shall be marked in accordance with ISO 6469-3.

NOTE For marking requirements for a voltage class A RESS or RESS subsystem when integrated into a voltage class B circuit see ISO 6469-3.

4.2 General safety requirements

The following requirements are general safety requirements, which apply when cited.

— The RESS shall not exhibit any evidence of leakage.

— The RESS shall not exhibit continuous emission of flames for more than 1 s or explosion.

— The RESS shall not exhibit any evidence of rupture.

— The voltage class B2 RESS shall maintain an isolation resistance according to 5.4.1.

Compliance shall be tested in accordance with 6.1.6.

5 Technical requirements

5.1 Mechanical requirements

The RESS shall provide the safety performance as specified below under mechanical loads due to vibration and mechanical shock, which an RESS will likely experience during the normal operation of a vehicle over its lifetime.

The general safety requirements in accordance with 4.2 shall be fulfilled.

Compliance shall be tested in accordance with 6.2.

5.2 Climatic requirements

5.2.1 Thermal shock cycling

The RESS shall provide the safety performance as specified below under a climatic load due to rapid temperature changes, which an RESS will likely experience during the normal operation of a vehicle.

The general safety requirements in accordance with 4.2 shall be fulfilled.

Compliance shall be tested in accordance with 6.3.1.

5.3 Simulated vehicle accident requirements

5.3.1 Vehicle crash

The RESS shall provide the safety performance at a vehicle crash, which shall comply with 5.3.1.1 and 5.3.1.2. Testing shall be performed at vehicle level or RESS level.

5.3.1.1 Inertial load at a vehicle crash

The RESS shall provide the safety performance under inertial loads caused by an acceleration which can occur at a vehicle crash. The general safety requirements in accordance with 4.2 shall be fulfilled. Compliance shall be tested in accordance with 6.4.1.1.2 or 6.4.1.2.

5.3.1.2 Contact force at a vehicle crash

The RESS shall provide the safety performance under contact forces which can occur at a vehicle crash. The general safety requirements in accordance with 4.2 shall be fulfilled.

For an RESS intended to be installed in vehicles with a gross mass exceeding 3,5 t, the requirements are deemed to be fulfilled, if the RESS is intended to be installed at a position higher than 700 mm above the ground (distance between the ground and the bottom surface of the RESS).

For an RESS intended to be installed in vehicles with a gross mass exceeding 7,5 t the requirements are deemed to be fulfilled, if the RESS is intended to be installed within a longitudinal chassis frame structure of the vehicle.

Compliance shall be tested in accordance with 6.4.1.1.3 or 6.4.1.2.

5.3.2 Immersion into water

The RESS shall provide the safety performance as specified below when it is exposed to water due to water immersion.

NOTE This requirement does not cover incidents in which the primary hazard for persons is caused by the presence of water, e.g. high flooding, flooded underground parking, flooded underpass.

The requirement is fulfilled if the RESS or RESS subsystem meets one of the following conditions:

— The RESS or RESS subsystem shall be tested in accordance with 6.4.2. During the test and during the post-test observation period of 2 h, the RESS or RESS subsystem shall not exhibit any evidence of continuous emission of flames for more than 1 s, or explosion.

— The RESS or RESS subsystem including all connectors, air ducts and connections for cooling attached is water protected. It shall be tested in accordance with IPX7 in ISO 20653 and no occurrence of water is allowed inside the RESS or RESS subsystem after the exposure to water. The test may be conducted with only the housing of an RESS or RESS subsystem and all connectors, air ducts and connections for cooling attached.

Minimal appearance of water due to the condensation of air humidity is possible and not considered as an occurrence of water. In case of doubt the test may be performed with coloured water.

5.3.3 Exposure to fire

This sub-clause applies to the RESS using flammable electrolyte only.

The RESS shall provide the safety performance as specified below when it is exposed to fire from outside of the vehicle. A thermal load can occur due to a fuel fire underneath the vehicle. Such a fire can be caused by fire from ignited spilled fuel either from the vehicle itself or a nearby vehicle. The intention is to provide time for the driver, passengers, and bystanders to evacuate.

During the test and during the specific post-test observation period for the exposure to fire, the RESS shall not exhibit any evidence of explosion.

Compliance shall be tested in accordance with 6.4.3.

The requirement is deemed to be fulfilled when the RESS is intended to be installed in the vehicle and mounted at a position higher than 1,5 m above the ground (distance between the ground and the bottom surface of the RESS subsystem).

5.4 Electrical requirements

5.4.1 Isolation resistance

For a voltage class B2 RESS its isolation resistance divided by its maximum working voltage shall be at least as follows:

— 100 Ω/V, if the RESS contains DC circuits only;

— 100 Ω/V, if the RESS contains AC circuits and additional AC protection in accordance with ISO 6469-3;

— 500 Ω/V, if the RESS contains AC circuits without additional AC protection in accordance with ISO 6469-3.

When the RESS is installed in a vehicle and conductively connected to a voltage class B2 electric circuit, a higher resistance value for the RESS is necessary to meet the requirements in ISO 6469-3.

NOTE For the isolation resistance required on a voltage class A or B1 RESS conductively connected to a voltage class B2 electric circuit see ISO 6469-3.

Compliance shall be tested according to the relevant test given in ISO 6469-3.

5.4.2 Clearance and creepage distance

For an open-type voltage class B RESS or RESS subsystem, where electrolyte leakage can occur, the following requirements shall apply:

NOTE An open-type lead acid battery is an example of an open-type voltage class B RESS.

The creepage distance between voltage class B terminals shall be as follows:

$$d \geq 0{,}25U + 5$$

where

d is the creepage distance in millimetres (mm);

U is the maximum working voltage of the RESS in volts (V).

The creepage distance between voltage class B live parts and the electric chassis shall be as follows:

$$d \geq 0{,}125U + 5$$

where

d is the creepage distance in millimetres (mm);

U is the maximum working voltage of the RESS in volts (V).

The clearance between voltage class B terminals shall be at least 2,5 mm.

5.4.3 Short-circuit protection

The RESS shall have a short-circuit protection and provide its safety performance in case of an external short-circuit as specified below when the RESS is operational (e.g. the contactor is closed). The requirements in a) or b) provide short-circuit protection.

a) The cross-sectional area of the live conductors of the RESS have a short-circuit current withstand rating (I^2t) according to the maximum short-circuit current of the RESS.

b) An overcurrent protection for the live conductors of an RESS according to their cross-sectional area is provided. The overcurrent protection is capable to interrupt a short-circuit current.

NOTE Short circuit is a specific case of overcurrent.

The general safety requirements in accordance with 4.2 shall be fulfilled.

Compliance shall be tested in accordance with 6.5.1.

5.5 Functional requirements

5.5.1 General

Functional requirements ensure the RESS safety performance in case of a failure on the vehicle level. Functional requirements are achieved by robust design or by a protection function. A protection function may be implemented on vehicle level. If the protection function is not implemented on RESS level, the RESS shall have a robust design, or only be used in a vehicle which implements the protection function. If a protection function is implemented on the vehicle level, it shall be effective under normal operating conditions and in case of a single fault.

5.5.2 Overcharge protection

When the RESS exceeds the upper SOC limits, the general safety requirements in accordance with 4.2 shall be fulfilled.

Compliance shall be tested in accordance with 6.6.2.

5.5.3 Overdischarge protection

This clause applies only to the RESS using electrochemical energy conversion.

When the RESS SOC falls below its lower limits, the general safety requirements in accordance with 4.2 shall be fulfilled.

Compliance shall be tested in accordance with 6.6.3.

5.5.4 Protection against internal overheating

The RESS shall provide the safety performance as specified below and protection against internal overheating when the internal temperatures are exceeding the maximum operating temperatures specified by the supplier and the RESS is operational. The protection against internal overheating

shall be effective in case of a failure of a thermal control or a cooling function, if such measures are implemented.

The general safety requirements in accordance with 4.2 shall be fulfilled.

Compliance shall be tested in accordance with 6.6.4.

5.6 Requirements for the emission of hazardous gases and other hazardous substances

For protection against toxicity hazards, the following requirements shall apply when hazardous gases and other hazardous substances can be emitted by the RESS.

No potentially dangerous concentration of hazardous gases and other hazardous substances shall be allowed anywhere in the driver, passenger and load compartments.

Only normal operating and environmental conditions as specified by the supplier shall be considered for this requirement.

Appropriate countermeasures shall manage first-failure situations.

6 Test procedures

6.1 General test conditions

6.1.1 Test types and post-test observation

If not otherwise specified, the tests described apply to the RESS or RESS subsystem referred to as device under test (DUT) in the following text.

The test sequence for a DUT shall be based on the agreement between the customer and the supplier. The re-use of the DUT and an exchange of its components in a test sequence are acceptable based on the agreement between the customer and the supplier.

The post-test observation period shall subsequently follow the test and shall last 1 h, if not otherwise specified.

Qualification of the personnel and safety of the test bench shall be provided by the test lab, e.g. over current protection.

6.1.2 Test parameters

6.1.2.1 Test temperature

Room temperature (RT) is (25 ± 2) °C.

6.1.2.2 Measurement accuracy

The accuracy of external measurement equipment shall be at least within the following tolerances:

— voltage: ±0,5 %;

— current: ±0,5 %;

— temperature: ±1 K.

The overall accuracy of externally controlled or measured values, relative to the specified or actual values, shall be at least within the following tolerances:

— voltage: ±1 %;

— current: ±1 %;

— temperature: ±2 K;

— time: ±0,1 %;

— mass: ±0,1 %;

— dimensions: ±0,1 %.

If required by the test procedure the values of time, temperature, current, and voltage shall be noted at least every 5 % of the estimated time for testing and the observation period.

6.1.3 DUT requirements and preparation of the DUT for testing

6.1.3.1 DUT requirements

The DUT shall comprise all parts specified by the customer (e.g. including mechanical and electrical connecting points for the mechanical test).

All necessary documentation and interface parts for the operation and connection of the DUT to the test equipment (i.e. connectors, plugs including cooling) shall be delivered to the test lab together with the DUT.

The DUT shall enable the specified tests, e.g. by specified test modes implemented in the RESS control unit and shall be able to communicate with the test bench via e.g. common communication buses.

The DUT may be equipped with additional sensors, wires, and support jigs, which are necessary to conduct the specific test or to obtain the required data for such a test. Such additional devices shall not influence the result with respect to the intended purpose of the test.

6.1.3.2 Preparation of the RESS subsystem and test bench

The RESS subsystem shall be connected with necessary electrical connections to the test bench equipment. The contactors, voltage, current, and temperature shall be controlled according to the requirements agreed between the customer and the supplier and according to the given test specification by the test bench equipment. The test bench shall enable the function for overcurrent protection of the RESS subsystem, if necessary, e.g. by the control of the RESS subsystem contactors. The cooling device shall be connected to the test bench equipment and operated according to the supplier's requirements and control strategy, unless otherwise specified by the test procedure.

6.1.3.3 Preparation of the RESS and test bench

The RESS shall be connected with necessary electrical connections to the test bench equipment. The RESS shall be controlled by the RESS control unit. The test bench equipment shall follow the operational limits provided by the RESS control unit via communication. The test bench equipment shall maintain the on/off requirements for the main contactors, if any, and the voltage, current, and temperature profiles according to the requirements of the given test procedure. The RESS cooling device and the corresponding cooling loop at the test bench equipment shall be operational according to the given test specifications and the controls by the RESS control unit. The RESS control unit shall enable the test bench equipment to perform the requested test procedure within the RESS operational limits. The overcurrent protection of the RESS shall be operational.

6.1.4 Preconditioning of the DUT

If not otherwise specified in this document, the following conditions shall apply:

— The DUT shall be conditioned by performing the standard cycle as specified in 6.1.5 to ensure an adequate stabilization of the DUT. The number of the SC shall be specified by the supplier or customer.

— Before each test, the SOC of the DUT shall be set to a value of the maximum SOC at normal operating conditions as agreed between the customer and the supplier.

— Each change of the SOC shall be followed by a rest period of 30 min.

— The ambient temperature shall be RT.

6.1.5 Standard cycle (SC)

6.1.5.1 General

This sub-clause applies only to the RESS using electrochemical energy conversion.

The purpose of the standard cycle (SC) is to ensure the same initial condition for each test of a DUT. An SC shall be performed prior to each test.

The SC shall be performed keeping the DUT at RT. The SC shall comprise a standard discharge (see 6.1.5.2), followed by a standard charge (see 6.1.5.3). Based upon the agreement between the customer and the supplier the DUT temperature may differ from RT provided that the DUT temperature has no impact on the test result.

If, for any reason, the time interval between the end of the SC and the start of a new test is longer than 3 h, the SC shall be repeated. Based upon the agreement between the customer and the supplier the time interval may be extended up to 24 h provided that the temperature is kept at RT during that period.

6.1.5.2 Standard discharge (SDCH)

Discharge rate: 1 C or other specific discharge regime according to the specifications given by the supplier.

Discharge limit: according to the specifications given by the supplier.

Rest period after the discharge: 30 min.

6.1.5.3 Standard charge (SCH)

The standard charge procedure shall be according to the specifications given by the supplier. The specifications shall include the end of the charge criteria and time limits for the overall charging procedure.

Rest period after the charge: 30 min.

6.1.6 Testing of general safety requirements

6.1.6.1 Evidence of leakage

The evidence of leakage shall be tested without disassembling any part of the DUT. Verification of electrolyte may be determined by visual inspection, litmus paper testing, and/or chemical analysis of the fluid after the observation period.

6.1.6.2 Evidence of rupture

The evidence of rupture shall be tested in accordance with ISO 20653 after the observation period.

6.1.6.3 Evidence of fire

The evidence of continuous emission of flames for more than 1 s shall be tested by visual inspection during the test and during the observation period.

NOTE Sparks and arcing are not considered as flames.

6.1.6.4 Evidence of explosion

The evidence of explosion shall be tested by visual inspection or appropriate means for detection of projectiles from the DUT during the test and during the observation period.

6.1.6.5 Isolation resistance

The isolation resistance shall be measured after the test and after the observation period. The measurement shall be conducted according to the relevant test procedures in ISO 6469-3 but without preconditioning and conditioning.

6.2 Mechanical test

6.2.1 General

NOTE It is assumed that RESS subcomponents are designed according to the relevant requirements of their respective standards.

The test shall be performed in two steps, vibration test in accordance with 6.2.2 and mechanical shock test in accordance with 6.2.3 and all spatial directions specified. The following test conditions shall apply:

— The whole test (vibration and mechanical shock) shall be conducted with the same DUT;

— The ambient temperature shall be (20 ± 10) °C.

The test order of vibration and mechanical shock shall be decided upon the agreement between the customer and the supplier.

6.2.2 Vibration

The DUT shall be tested in all mounting orientations it is foreseen to be installed in a vehicle.

If several mounting orientations are supported, it is sufficient to test with the maximum power spectral density (PSD) values of Tables 1 to 3 only.

The test shall be performed by test option 1 or test option 2.

6.2.2.1 Test option 1

The DUT shall be mounted on the appropriate test equipment. It shall be subjected to vibration by random profiles in three spatial directions (vertical direction Z, longitudinal direction X and transverse direction Y) with the PSD values as given in Figure 1 and the corner points in Table 1 to Table 3. The test shall be performed in the following sequence of the three spatial directions: starting with Z, followed by X and finally Y. The test sequence may be changed upon the agreement between the customer and the supplier. The test duration per spatial direction shall be 12 h.

Table 1 — Values for the PSD in Z-direction

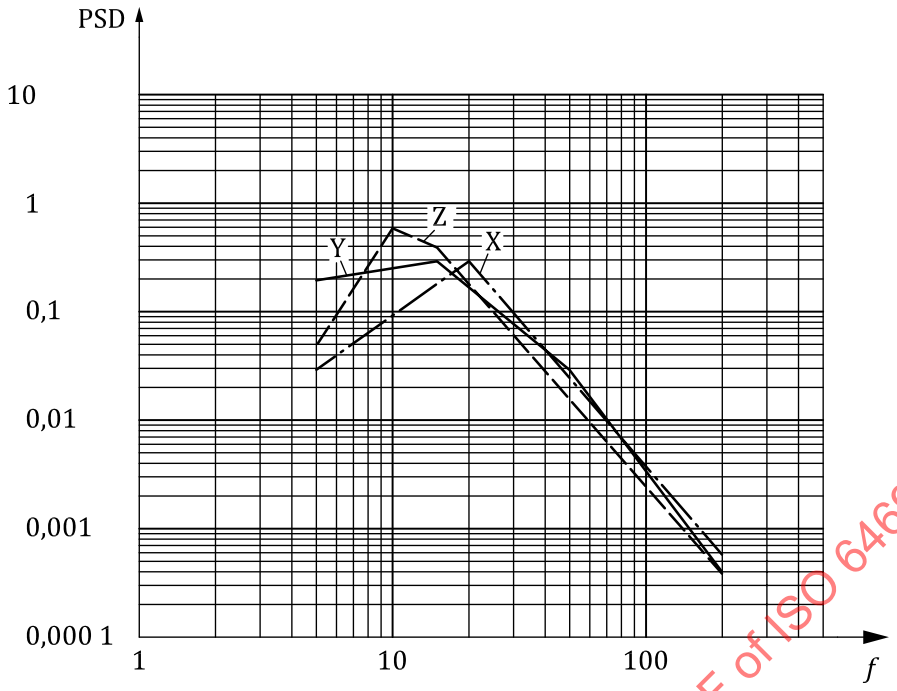
Frequency Hz	PSD $(m/s^2)^2/Hz$
5	0,048 1
10	0,577 4
15	0,384 9
200	0,000 4
RMS	2,64 m/s^2

Table 2 — Values for the PSD in X-direction

Frequency Hz	PSD $(m/s^2)^2/Hz$
5	0,028 9
20	0,288 7
200	0,000 6
RMS	2,34 m/s^2

Table 3 — Values for the PSD in Y-direction

Frequency Hz	PSD $(m/s^2)^2/Hz$
5	0,192 5
15	0,288 7
50	0,028 9
200	0,000 4
RMS	2,51 m/s^2



Key

PSD power spectral density

f frequency

Figure 1 — PSD spectra for Z-, X- and Y-direction

The control parameters in Table 4 shall be used for the test equipment:

Table 4 — Control parameters for the vibration test

statistical DOF	minimum 120
minimum frequency resolution	(1,25 ± 0,25) Hz
crest factor (sigma-clipping)	3 σ
warning limits	±3 dB
abort limits	±6 dB

6.2.2.2 Test option 2

The test may be performed as an operation load simulation test based on vehicle measurements. For test option 2 the overall mechanical load shall not be below the mechanical load in test option 1. The verification may be provided by calculation. For this calculation the damage D_A caused by vibration loads during vehicle measurement shall be greater or equal than the damage D_B calculated from the mechanical load in option 1. An example for the calculation of damage is given in Annex A. An example of an OEM specific test, which complies with this requirement, is provided in Annex B.

6.2.3 Mechanical shock

The DUT shall be mounted on the appropriate test equipment and shall be subjected to shocks with a test profile of half-sinusoidal acceleration in six spatial directions: ±(vertical direction Z), ±(longitudinal direction X) and ±(transverse direction Y).

Perform the test in accordance with IEC 60068-2-27 using the test parameters in Table 5.

Table 5 — Test parameters for the mechanical shock

Procedure	Requirement
Pulse-Shape	Half-sinusoidal
Acceleration	±Z: 70 m/s^2 ±X: 50 m/s^2 ±Y: 30 m/s^2
Duration	6 ms
Number of shocks	6 per test direction

6.3 Climatic test

6.3.1 Thermal shock cycling

If the DUT utilizes liquid cooling, the coolant shall be present as for a normal operation. The active cooling if any shall be disabled.

The DUT shall be stored for at least 6 h at an ambient temperature T_{max} equal to 60 °C ± 2 K followed by storage for at least 6 h at an ambient temperature equal to −40 °C ± 2 K. A higher temperature for T_{max} may be used if agreed between the supplier and the customer.

The transient time between the ambient temperature extremes shall be 30 min or less. This procedure shall be repeated until a minimum of 5 total cycles are completed.

Then, the DUT shall be stored for 24 h at an ambient temperature of (20 ± 10) °C. After the storage for 24 h, a standard cycle as described in 6.1.5 shall be conducted, if not inhibited by the DUT.

The DUT may be moved between two test chambers if the temperature conditions are fulfilled for each test chamber.

6.4 Simulated vehicle accident tests

6.4.1 Vehicle crash

The tests may be conducted on the component or vehicle level. The selection of either of the described options shall be according to the agreement between the customer and the supplier.

6.4.1.1 RESS level based test

6.4.1.1.1 General

The DUT shall be installed on the test rig by the fixtures provided for the purpose of attaching the RESS or RESS subsystem to the vehicle or according to the agreement between the customer and the supplier.

The ambient temperature shall be (20 ± 10) °C.

In case of a liquid-cooled RESS, the DUT shall be filled with the standard coolant, and, according to the agreement between the customer and the supplier, the vehicle cooling circuit can be substituted with a representative external cooling system or the connecting ports shall be sealed to retain the coolant inside the piping within the DUT.

6.4.1.1.2 Inertial load at a vehicle crash

Testing shall be conducted at least once in the same direction of the shock that occurs in the vehicle during a vehicle crash test. For medium-duty trucks, midi buses, heavy-duty trucks and buses, a test direction determined by the customer and verified to the vehicle application shall apply. For each of these directions, the test shall be conducted according to one of the options described below. If the

orientation of the DUT in the vehicle or the direction of the inertial load is not known, the DUT shall be tested in all six spatial directions.

Electronic or mechanical switching devices (e.g. contactors), if present, shall be closed and relevant control units, if part of the DUT, shall be operational.

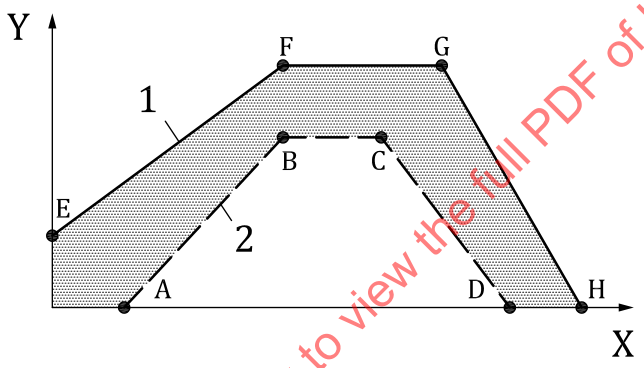
In case of performing the test without the relevant control units, the following steps shall be performed after the test:

— the control units shall be activated;

— electronic or mechanical switching devices shall be closed;

— the verification of 4.2 shall be performed.

The test shall be performed using the pulse shape and the values for time and acceleration within the corridor, given by the values for the upper bound and the lower bound in Figure 2, by applying the time-acceleration values from Table 6 to Table 8 for the gross mass of the vehicle intended for the application of the DUT, or according to a test profile determined by the customer and verified to the vehicle application.



Key

1 maximum curve
2 minimum curve
Y acceleration
X time

Figure 2 — Generic description of test pulses

Table 6 — Area of values for acceleration pulses for vehicles with gross mass not exceeding 3,5 t

	Time ms	Acceleration (longitudinal) g	Acceleration (transversal) g
A	20	0	0
B	50	20	8
C	65	20	8
D	100	0	0
E	0	10	4,5
NOTE The values for longitudinal acceleration are taken from UN Regulation No.17. It can as well be applied to the RESS or RESS subsystem.			

Table 6 *(continued)*

	Time ms	Acceleration (longitudinal) g	Acceleration (transversal) g
F	50	28	15
G	80	28	15
H	120	0	0
NOTE The values for longitudinal acceleration are taken from UN Regulation No.17. It can as well be applied to the RESS or RESS subsystem.			

Table 7 — Area of values for acceleration pulses for medium-duty trucks and midi buses

	Time ms	Acceleration (longitudinal) g	Acceleration (transversal) g
A	20	0	0
B	50	10	5
C	65	10	5
D	100	0	0
E	0	5	2,5
F	50	17	10
G	80	17	10
H	120	0	0

Table 8 — Area of values for acceleration pulses for heavy-duty trucks and buses

	Time ms	Acceleration (longitudinal) g	Acceleration (transversal) g
A	20	0	0
B	50	6,6	5
C	65	6,6	5
D	100	0	0
E	0	4	2,5
F	50	12	10
G	80	12	10
H	120	0	0

6.4.1.1.3 Contact force at a vehicle crash

The DUT shall be crushed between a flat support and one of the crush probes described below according to the agreement between the customer and the supplier:

— a crush plate as described in Figure 3;

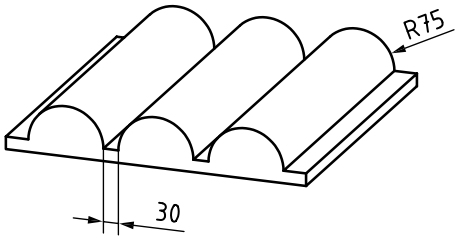


Figure 3 — Crush plate with dimensions of 600 mm × 600 mm or smaller

— a half cylinder with a diameter of 150 mm as described in Figure 4. The half cylinder shall be long enough to extend past the edge of the DUT by a minimum of 50 mm at each end.

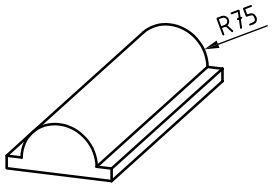


Figure 4 — Half cylinder with a diameter of 150 mm

The tests shall be performed on all axes derived from vehicle crash tests as determined by the customer.

It is not required that all test conditions are conducted on a single DUT.

The crush probe shall be applied according to one of the following options.

— The axis of the cylinder(s) shall be oriented vertically with respect to the supposed position of the RESS or RESS subsystem in the vehicle. The centre of the crush probe shall be located at the geometric centre of the projected plane of the DUT which is perpendicular to the direction of crush.

— The probe shall be oriented according to the customer's specification. The direction of travel of the RESS or RESS subsystem relative to its installation in the vehicle shall be considered.

The applied force shall be (100 − 0/+ 5) kN or a value determined by the customer depending on expected forces in vehicle crash tests. These values shall be based on appropriate analyses, e.g. vehicle crash tests or vehicle crash simulations.

The test shall be performed with a ramp-up time of less than 3 min and a hold time of at least 100 ms but not exceeding 10 s.

If a vehicle structure is used as a protection device against the contact force, then that vehicle structure can be included in the test according to the agreement between the customer and the supplier.

6.4.1.2 Vehicle level based test

For testing the DUT on the vehicle level the DUT shall be installed in a vehicle as intended for the normal operation.

A test profile determined by the vehicle manufacturer and verified to the vehicle application shall apply.

6.4.2 Immersion into water

Immerse the DUT in ambient temperature salt water (3,5 % – 5 % by weight NaCl in H_2O) for 2 h.

The DUT shall be built up and prepared with all connectors, ducts and flanges, interfaces for cooling and coolant according to the vehicle manufacturer's specification for vehicle operation.

If the water depth *w* is defined, immerse the DUT as deep as the RESS installed in the vehicle operated in the specified water depth *w*.

If the water depth *w* is not defined, the immersion depth shall be 1 m (deepest housing location) or 0,15 m water above the highest housing location, if the housing is larger than 0,85 m.

6.4.3 Exposure to fire

6.4.3.1 Installations

a) Testing fixture

The DUT shall be mounted in a testing fixture simulating actual mounting conditions as far as possible; no combustible material shall be used for this with the exception of material that is part of the RESS. The method whereby the DUT is fixed in the fixture shall correspond to the relevant specifications for its installation in a vehicle.

In the case of an RESS designed for a specific vehicle use, vehicle parts which affect the course of the fire in any way shall be taken into consideration. For this purpose, the DUT may be installed in the relevant vehicle body.

If the DUT is not installed in the vehicle body, the DUT shall be placed on a grating table positioned above the pan, in an orientation according to the agreement between the customer and the supplier. The grating table shall be constructed by steel rods, with a diameter of 6 mm to 10 mm, with 40 mm to 60 mm in between. If needed, the steel rods can be supported by flat steel parts.

In case of a liquid-cooled RESS, the DUT shall be filled with the standard coolant, according to the agreement between the customer and the supplier. The connection to the external cooling circuit can be simulated according to the agreement between the customer and the supplier, or the connecting ports shall be sealed to retain the coolant inside the piping within the DUT.

b) Fuel and pan

The flame to which the DUT is exposed shall be obtained by burning a commercial fuel for positive-ignition engines (hereafter called "fuel") in a pan. The quantity of the fuel shall be sufficient to permit the flame, under free-burning conditions, to burn for the whole test procedure.

The fire shall cover the whole area of the pan during the whole fire exposure. The pan dimensions shall be chosen so as to ensure that the sides of the DUT are exposed to the flame. The pan shall therefore exceed the horizontal projection of the DUT by at least 200 mm but not more than 500 mm.

The sidewalls of the pan shall not project more than 80 mm above the level of the fuel at the start of the test.

The pan filled with the fuel shall be placed under the DUT in such a way that the distance between the level of the fuel in the pan and the bottom of the DUT corresponds to the design height of the DUT above the road surface at the unloaded state of the vehicle or if the height is not specified approximately 500 mm or according to the agreement between the customer and the supplier. If it is the intent to use vehicle parts that influence the course of the fire, then they can be integrated with the DUT which can define the relative position of the DUT above the level of the fuel.

Either the pan or the testing fixture, or both, shall be freely movable in the horizontal direction.

c) Screen

During phase C of the test, the pan shall be covered by a screen. The screen shall be placed (30 ± 10) mm above the fuel level measured prior to the ignition of the fuel. The screen shall be made of a refractory material, as prescribed in Annex C. There shall be no gap between the bricks and they shall be supported over the fuel pan in such a manner that the holes in the bricks are not obstructed. The length and width of the frame shall be 20 mm to 40 mm smaller than the interior dimensions of the pan so that a gap of 10 mm to 20 mm exists between the frame and the wall of

the pan to allow ventilation. Before the test, the screen shall be at least at the ambient temperature. The firebricks can be wetted in order to guarantee repeatable test conditions.

6.4.3.2 Ambient conditions

The ambient temperature of the test shall be 0 °C or higher. If the tests are carried out in the open air, sufficient wind protection shall be provided and the wind velocity at the pan level shall not exceed 2,5 km/h.

6.4.3.3 Conditions for the exposure to fire

— Phase A: Pre-heating:

  The fuel in the pan shall be ignited at a distance of at least 3 m from the DUT. After 60 s pre-heating, the pan shall be placed under the DUT by moving either the DUT fixture or the pan. This phase A can be omitted if the temperature of the fuel before the test is 20 °C or higher.

— Phase B: Direct exposure to flame:

  The DUT shall be exposed to the flame from the freely burning fuel for 70 s.

— Phase C: Indirect exposure to flame:

  As soon as phase B has been completed, the screen shall be placed between the burning pan and the DUT. The DUT shall be exposed to this reduced flame for a further 60 s.

Instead of conducting phase C of the test, phase B can, according to the agreement between the customer and the supplier, be continued for an additional 60 s.

6.4.3.4 End of the fire exposure and post-test observation

The burning pan shall be removed and placed more than 3 m away from the DUT. The fire of the pan shall be immediately extinguished while no extinguishing of the DUT shall be conducted. The post-test observation period for the exposure to fire shall start at the removal of the pan. It shall last until the surface temperature of the DUT has decreased to the ambient temperature or has been decreasing for a minimum of 3 h.

6.5 Electrical test

6.5.1 Short circuit

If an RESS subsystem is tested the overcurrent protection as intended by the design shall be included in the DUT.

The test shall be conducted using a connection for the external short circuit with a resistance not exceeding 5 mΩ.

The test shall be terminated if one of the following conditions is met:

— A short-circuit protection function interrupts the short-circuit current.

— The temperature change is less than 4 K within a period of 1 h. The internal temperature measurement of the DUT shall be used, if present and operational. Otherwise the temperature shall be measured at the casing.

The test may be conducted at a higher temperature than RT as given in 6.1.4 according to the agreement between the customer and the supplier.

6.6 Functional tests

6.6.1 General procedures

Data acquisition/monitoring shall be continued for 1 h after the charging or discharging is stopped.

Data sampling, especially for DUT voltage, current and temperature, shall be performed with an adequate sampling rate, e.g. 100 ms for the evaluation of the current shut-off function.

The condition of test termination shall be recorded.

The isolation resistance monitoring system of the DUT or the test equipment, if it possibly interrupts the test, shall be disabled.

6.6.2 Overcharge protection

The DUT shall be charged to maximum SOC in the normal operation as agreed by the supplier and the customer. The ambient temperature shall be (20 ± 10) °C. The cooling system shall be operated, and the main contactors shall be closed, if present. The RESS shall be controlled by the RESS control unit. The test shall be performed with all the related functions of the DUT including the overcharge protection function and the charge current control function, if present, fully operational.

The DUT shall be charged with the maximum charge current as agreed by the supplier and the customer.

The test shall be terminated when one of the following conditions is met;

— The RESS overcharge protection function interrupts the charge current.

NOTE The device which interrupts the charge current could not be a part of an RESS subsystem.

— The charging continues for 12 h.

— The RESS temperature rise decreases until the gradient is less than 2 K within 1 h.

— The SOC or voltage or maximum RESS temperature exceeds an upper limit, as agreed by the customer and the supplier. In this case, the test is failed.

— The general safety requirements in accordance with 4.2 are violated. In this case, the test is failed.

If the RESS uses battery cells, the temperature of the cell with the highest temperature shall be considered.

6.6.3 Overdischarge protection

The DUT shall be charged to a SOC in the normal operation as agreed by the customer and the supplier. The ambient temperature shall be 20 ± 10 °C. The cooling system is operated, and the main contactors are closed, if present. The RESS shall be controlled by the RESS control unit. The test shall be performed with all the related functions of the DUT including the overdischarge protection function and the discharge current control function, if present, fully operational.

The DUT shall be discharged at a constant current rate within the range of the vehicle normal operation as agreed by the customer and the supplier.

The overdischarging shall be terminated when one of the following conditions is met:

— The RESS overdischarge protection function interrupts the discharge current.

NOTE The device which interrupts the discharge current could not be a part of an RESS subsystem.

— The discharging continues until the RESS voltage reaches 0 V.