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Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems —

Part 3: Safety performance requirements

Véhicules routiers à propulsion électrique — Spécifications d'essai pour packs et systèmes de batterie de traction aux ions lithium —

Partie 3: Exigences de performance de sécurité

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Foreword

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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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 12405 consists of the following parts, under the general title *Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems*:

— *Part 1: High-power applications*

— *Part 2: High-energy applications*

— *Part 3: Safety performance requirements*

Introduction

Lithium-ion battery systems are efficient rechargeable energy storage systems for electrically propelled road vehicles. The requirements for lithium-ion battery systems to be used as power source for the propulsion of electric road vehicles are significantly different to those batteries used for consumer electronics or for stationary applications.

Lithium-ion batteries can store electricity at relatively high-energy density compared to other battery chemistries currently available. Under current state of art, most lithium-ion batteries use organic electrolytes which are classified as Class 3 “flammable liquid” under the “UN Recommendations on the Transport of Dangerous Goods — Model Regulations”. Therefore, mitigating potential hazards associated with fire or explosion of lithium-ion batteries is considered an important issue.

This part of ISO 12405 provides specific test procedures and related requirements to ensure an appropriate and acceptable level of safety of lithium-ion battery systems specifically developed for propulsion of road vehicles.

Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems —

Part 3: **Safety performance requirements**

1 Scope

This part of ISO 12405 specifies test procedures and provides acceptable safety requirements for voltage class B lithium-ion battery packs and systems, to be used as traction batteries in electrically propelled road vehicles. Traction battery packs and systems used for two-wheel or three-wheel vehicles are not covered by this part of ISO 12405. This part of ISO 12405 is related to the testing of safety performance of battery packs and systems for their intended use in a vehicle. This part of ISO 12405 is not intended to be applied for the evaluation of the safety of battery packs and systems during transport, storage, vehicle production, repair, and maintenance services.

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

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

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

ISO 12405-1:2011, *Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 1: High-power applications*

ISO 12405-2:2012, *Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 2: High-energy applications*

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

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
battery control unit
BCU
electronic device that controls, manages, detects, or calculates electric and thermal functions of the battery system that provides communication between the battery system and other vehicle controllers

Note 1 to entry: See also Annex A for further explanation.

3.2
battery pack
energy storage device that includes cells or cell assemblies normally connected with cell electronics, voltage class B circuit, and overcurrent shut-off device, including electrical interconnections and interfaces for external systems

Note 1 to entry: For further explanation, see A.2.

Note 2 to entry: Examples of external systems are cooling, voltage class B, auxiliary voltage class A, and communication.

3.3
battery pack subsystem
representative portion of the battery pack

3.4
battery system
energy storage device that includes cells or cell assemblies or battery pack(s), as well as electrical circuits and electronics

Note 1 to entry: For further explanation, see A.3.1 and A.3.2. Battery system components can also be distributed in different devices within the vehicle.

Note 2 to entry: Examples of electronics are the BCU and contactors.

3.5
bus
vehicles 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

3.6
capacity
total number of ampere-hours that can be withdrawn from a fully charged battery under specified conditions

3.7
cell electronics
electronic device that collects and possibly monitors thermal or electric data of cells or cell assemblies and contains electronics for cell balancing, if necessary

Note 1 to entry: The cell electronics can include a cell controller. The functionality of cell balancing can be controlled by the cell electronics or it can be controlled by the BCU.

3.8
customer
party that is interested in using the battery pack or system and, therefore, orders or performs the test

EXAMPLE A vehicle manufacturer.

3.9
device under test
DUT
in this part of ISO 12405, a battery pack or battery system

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 surroundings of the DUT

Note 1 to entry: The kinetic energy of flying debris from the battery pack or system can be sufficient to cause damage to the surroundings of the DUT as well.

3.11
fire
continuous emission of flames from a DUT (approximately more than 1 s)

Note 1 to entry: Sparks and arcing are not considered as flames.

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

3.13
high-energy application
characteristic of device or application for which the numerical ratio between maximum allowed electric power output (power in W) and electric energy output (energy in Wh) at a 1 C discharge rate at RT for a battery pack or system is typically lower than 10

Note 1 to entry: Typically, high-energy battery packs and systems are designed for applications in BEVs.

3.14
high-power application
characteristic of device or application for which the numerical ratio between maximum allowed electric power output (power in W) and electric energy output (energy in Wh) at a 1 C discharge rate at RT for a battery pack or system is typically equal to or higher than 10

Note 1 to entry: Typically, high-power battery packs and systems are designed for application in HEVs and FCVs.

3.15
isolation resistance
resistance between live parts of the voltage class B electric circuit and the electric chassis, as well as the voltage class A system

3.16
leakage
escape of liquid or gas from a DUT except for venting

3.17
maximum working voltage
highest value of a.c. voltage (rms) or of d.c. voltage, which can occur in an electrical system under any normal operating conditions according to the battery manufacturer’s specifications, disregarding transients

3.18
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

3.19
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

3.20
rated capacity
supplier’s specification of the total number of ampere-hours that can be withdrawn from a fully charged battery pack or system for a specified set of test conditions such as discharge rate, temperature, discharge cut-off voltage, etc.

3.21
room temperature
RT
temperature of (25 ± 2) °C

3.22
rupture
loss of mechanical integrity of the enclosure of the DUT resulting in openings that do not fulfil protection degree IPXXB according to ISO 20653

Note 1 to entry: The kinetic energy of released material is not sufficient to cause structural and/or physical damage to the surrounding of the DUT.

3.23
state of charge
SOC
available capacity in a battery pack or system expressed as a percentage of rated capacity

3.24
supplier
party that provides battery systems and packs

EXAMPLE A battery manufacturer.

3.25
venting
release of excessive pressure from a DUT intended by design to preclude rupture or explosion

3.26
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

Note 1 to entry: See ISO 6469-3.

3.27
voltage class B
classification of an electric component or circuit with a maximum voltage of (>30 and ≤1 000) V a.c. (rms) or (>60 and ≤1 500) V d.c., respectively

Note 1 to entry: See ISO 6469-3.

4 Symbols and abbreviated terms

a.c.	alternating current
BCU	battery control unit
BEV	battery electric vehicle
d.c.	direct current
DUT	device under test
FCV	fuel cell vehicle
HEV	hybrid electric vehicle
RESS	rechargeable energy storage system
RT	room temperature [(25 ± 2) °C]
SOC	state of charge
UNECE	United Nations Economic Commission for Europe

5 General requirements

5.1 General conditions

A battery pack or system to be tested according to this part of ISO 12405 shall fulfil the following requirements.

— Electrical safety design shall be approved according to the requirements given in ISO 6469-1 and ISO 6469-3.

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

— A battery system shall enable the specified tests, e.g. by specified test modes implemented in the BCU, and shall be able to communicate with the test bench *via* common communication buses.

— The DUT can also be equipped with additional sensors, wires, and support jig, 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.

If not otherwise specified, the tests described apply to battery packs and systems.

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

The status of the DUT, e.g. new product, tested, or used, shall be agreed upon between the customer and the supplier before testing. The history of the DUT shall be documented.

When reference to ISO 12405-1 and ISO 12405-2 is made, only the test procedure in the corresponding clause shall apply. In this case, the test procedures and pre-conditions (e.g. temperatures, SOC) shall be selected according to the battery packs or systems application. For high-power applications, refer to ISO 12405-1, and for high-energy applications, refer to ISO 12405-2.

If not otherwise specified, the following conditions shall apply.

— The test temperature shall be RT.

— Before each test, the DUT shall be equilibrated at the test temperature. The thermal equilibration is reached, if during a period of 1 h without active cooling the deviations between test temperature and temperature of all cell temperature measuring points are lower than ±2 K.

— Before each test, the SOC of the DUT shall be set to a value agreed upon between the customer and the supplier but at least 50 % SOC for high-power applications. For high-energy applications, the SOC shall be set to maximum SOC at normal operation.

— Each charge and each SOC change shall be followed by a rest period of 30 min.

— The conduction of component-based testing or vehicle-based testing is optional. The selection of either of the described options shall be according to the agreement between the customer and the supplier.

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 %.

All values (time, temperature, current, and voltage) shall be noted at least every 5 % of the estimated discharge and charge time, except if it is noted otherwise in the individual test procedure.

If any test in this part of ISO 12405 is performed on the vehicle, the same test on battery pack or system level is not necessary.

5.2 Test sequence plan

5.2.1 General

The test sequence for an individual battery pack or system or a battery pack subsystem shall be based on the agreement between the customer and the supplier.

The re-use of the battery system and/or components in multiple tests is acceptable based on the agreement between the customer and the supplier.

5.3 Preparation of the DUT for testing

5.3.1 Preparation of battery pack

If not otherwise specified, the battery pack shall be connected with voltage class B and voltage class A connections to the test bench equipment. Contactors, available voltage, current, and temperature data shall be controlled according to the supplier's requirements and according to the given test specification by the test bench equipment. The passive overcurrent protection shall be maintained by the test bench equipment, if necessary *via* disconnection of the battery pack main contactors. The cooling device can be connected to the test bench equipment and operated according to the supplier's requirements.

5.3.2 Preparation of battery system

If not otherwise specified, the battery system shall be connected with voltage class B, voltage class A, and cooling system and BCU to the test bench equipment. The battery system shall be controlled by the BCU. The test bench equipment shall follow the operational limits provided by the BCU via bus communication. The test bench equipment shall maintain the on/off requirements for the main contactors and the voltage, current, and temperature profiles according to the requested requirements of the given test procedure. The battery system 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 BCU. The BCU shall enable the test bench equipment to perform the requested test procedure within the battery system operational limits. If necessary, the BCU program shall be adapted by the supplier for the requested test procedure. The active and passive overcurrent protection device shall be operational by the battery system. Active overcurrent protection shall be maintained by the test bench equipment, too, if necessary, *via* request of disconnection of the battery system main contactors.

5.4 Pre-conditioning cycles

5.4.1 DUT

If not otherwise specified, this test applies to each subsequent test of battery packs and systems.

5.4.2 Purpose

The DUT shall be conditioned by performing some electrical cycles, before starting the real testing sequence, in order to ensure an adequate stabilization of the battery pack or system performance.

5.4.3 Test procedure

The test procedure for pre-conditioning cycles shall apply according to 6.1.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT.

The battery pack or system shall be considered as pre-conditioned if the discharge capacity during two consecutive discharges does not change by a value greater than 3 % of the rated capacity. The pre-conditioning cycles are not necessary if the requirement is already fulfilled by an equivalent procedure.

5.5 General safety requirements

The following requirements are standard requirements, which apply when cited.

During the test and for a 1 h post-test observation period, the DUT shall not exhibit evidence of leakage, rupture, fire, or explosion. The evidence of leakage shall be verified by visual inspection without disassembling any part of the DUT.

The DUT shall maintain an isolation resistance of at least 100 Ω/V, if not containing a.c., or 500 Ω/V, if containing a.c.. When the DUT is integrated in a whole electric circuit, a higher resistance value for the DUT might be necessary. After the post-test observation period, the isolation resistance shall be measured in accordance with ISO 6469-1 without climatic pre-conditioning and conditioning.

NOTE DUT in this part of ISO 12405 is equivalent to RESS in ISO 6469-1.

6 Mechanical tests

6.1 Vibration

6.1.1 Purpose

The purpose of this test is to verify the safety performance of the DUT under a mechanical load due to vibration, which a battery system will likely experience during the normal operation of a vehicle.

6.1.2 Test procedure

Choose one of the following two options:

1) vibration according to 8.3.2.1 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT;

2) vibration profile as given by the customer, specifically applicable to the vehicle(s) in which the battery will be used.

NOTE 1 A vibration profile determined by the customer is an option described in ISO 12405-1 or ISO 12405-2.

NOTE 2 A vibration profile is given in UN ECE R100–02.

In case of liquid- or refrigerant-cooled battery systems, the DUT shall be filled with the specified coolant. The connection to an external cooling circuit shall be maintained according to the battery manufacturer's specifications or the connecting ports shall be sealed to retain the coolant inside the piping within the DUT.

NOTE 3 This test can be performed using a battery pack subsystem (see 5.1).

6.1.3 Requirements

Requirements as given in 5.5 shall apply.

6.2 Mechanical shock

6.2.1 Purpose

The purpose of this test is to verify the safety performance of the DUT under a mechanical load due to mechanical shock, which a battery system will likely experience during the normal operation of a vehicle.

NOTE Mechanical shock considers driving operations, such as deceleration in sudden braking situations or driving over road bumps or pot holes. It does not include a vehicle crash scenario.

6.2.2 Test procedure

Choose one of the following two options:

1) mechanical shock according to 8.4.2. of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT;

2) mechanical shock profile as given by the customer, specifically applicable to the vehicle(s) in which the battery will be used.

NOTE 1 A mechanical shock profile determined by the customer is an option described in ISO 12405-1 or ISO 12405-2.

NOTE 2 If the DUT is tested with a fixture according to the vehicle application, a lower acceleration value can apply.

NOTE 3 This test can be performed using a battery pack subsystem (see 5.1).

NOTE 4 A shock profile is given in UN ECE R100–02.

6.2.3 Requirements

Requirements as given in 5.5 shall apply.

7 Climatic tests

7.1 Dewing (temperature change)

7.1.1 Purpose

Simulates a climatic load which causes dewing derived from vehicle operation, which battery packs and systems will likely experience during service life.

7.1.2 Test procedure

According to 8.1.2 of ISO 12405-1:2011 or ISO 12405-2:2012.

7.1.3 Requirements

Requirements as given in 5.5 shall apply.

7.2 Thermal shock cycling

7.2.1 Purpose

The purpose of this test is to verify the ability of the DUT to withstand sudden changes in ambient temperature. The test simulates rapid temperature changes, which battery packs and systems would likely experience during service life.

7.2.2 Test procedure

The DUT shall undergo a specified number of temperature cycles, which start at ambient temperature followed by high and low temperature cycling in accordance with 8.2.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT.

If the DUT utilizes liquid cooling, the coolant shall be present as for normal operation but all thermal control shall be non-operational.

NOTE The following test parameters can be chosen:

— maximum ambient temperature: (60 ± 2) °C;

— time at temperature extremes: 6 h.

7.2.3 Requirements

Requirements as given in 5.5 shall apply.

8 Simulated vehicle accidents

8.1 Inertial load at vehicle crash

8.1.1 Purpose

The purpose of this test is to verify the safety performance of the DUT under inertial loads caused by acceleration which can occur at a vehicle crash.

This test can be omitted if, for the test according to 8.2, the vehicle-based test according to option 8.2.2 b) is conducted.

8.1.2 Test procedure

Testing shall be conducted at least once in the same direction of the shock that occurs in the vehicle during the vehicle crash as specified in national or regional regulations. For medium-duty trucks, midi buses, heavy-duty trucks, and buses, a test direction determined by the vehicle manufacturer 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 according to option a).

a) Battery pack or system testing outside of a vehicle

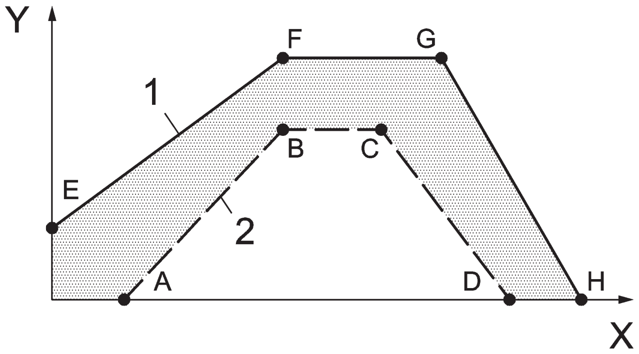
The DUT shall be installed on the test rig by the fixtures provided for the purpose of attaching the battery pack or system to the vehicle or according to the agreement between the customer and the supplier.

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

In case of a liquid-cooled battery system, 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.

Contactors shall be closed and relevant control units, if part of the DUT, shall be operational.

The test shall be performed using pulse shape and values for time and acceleration within the corridor, given by the values for upper bound and lower bound in Figure 1, by applying the time-acceleration values from Tables 1 to 3 for the gross mass of the vehicle intended for the application of the battery packs and systems, 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 1 — Generic description of test pulses

Table 1 — 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
F	50	28	15
G	80	28	15
H	120	0	0

NOTE The values in Table 1 for longitudinal acceleration are taken from UN ECE R17.[5] It might as well be applied to battery packs and systems.

Table 2 — 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 3 — 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

b) Battery pack or system testing when installed in a vehicle

For testing the DUT when installed in a vehicle as intended for normal operation, the relevant national or regional regulation on vehicle crash tests shall apply.

For medium-duty trucks, midi buses, heavy-duty trucks, and buses a test profile determined by the vehicle manufacturer and verified to the vehicle application shall apply.

If vehicle structure or a battery pack or system protection device (e.g. protection frame) is used as part or all of the battery pack or system enclosures, then that vehicle structure can be included in the test.

8.1.3 Requirements

For option 8.1.2 a), requirements as given in 5.5 shall apply.

For option 8.1.2 b), the relevant requirements of national or regional post-crash safety regulations shall apply.

8.2 Contact force at vehicle crash

8.2.1 Purpose

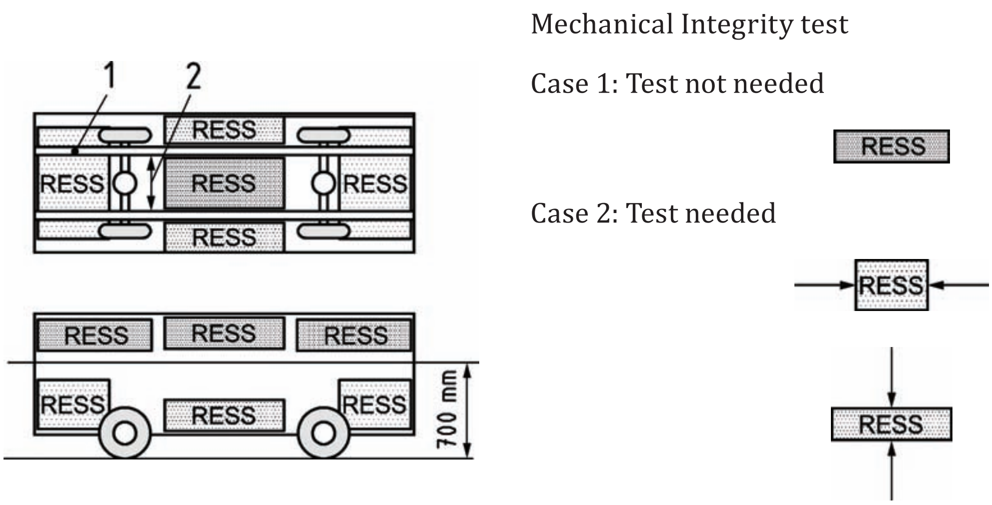
The purpose of this test is to verify the safety performance of the DUT under contact forces which can occur at a vehicle crash.

This test can be omitted if, for the test according to 8.1, the vehicle-based test according to option 8.1.2 b) is conducted.

8.2.2 Test procedure

For vehicles with a gross mass exceeding 3,5 t, this test applies to the DUT only, if it is intended to be installed at a position lower than 700 mm from the ground (measured at the bottom surface of the RESS), see Figure 2.

This test does not apply if the DUT is intended to be installed within a longitudinal chassis frame structure in vehicles with a gross mass exceeding 7,5 t, see Figure 2.



Key

1 frame

2 between frames

Figure 2 — Application of mechanical integrity test to RESS concerning RESS position

The test shall be conducted according to one of the options described below.

a) Battery pack or system test

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

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

In case of a liquid-cooled battery system, the DUT shall be filled with the standard coolant, and, according to 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.

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;

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

The tests shall be performed on all axes derived from vehicle crash tests in accordance with national or regional regulations and as determined by the customer. If no national or regional regulation exists, the customer can specify the relevant axes.

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 battery pack or system 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 battery pack or system 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 analysis, 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 vehicle structure is used as part or all of the battery enclosures, then that vehicle structure can be included in the test according to the agreement between the customer and the supplier.

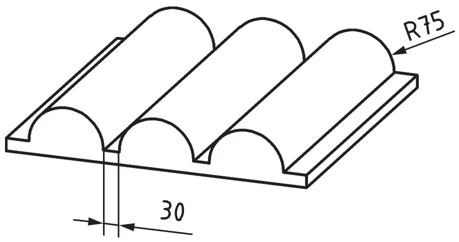


Figure 3 — Crush plate with dimensions of 600 mm × 600 mm or smaller

b) Battery pack or system testing when installed in a vehicle

For testing the DUT when installed in a vehicle as intended for normal operation, the relevant national or regional regulation on vehicle crash tests shall apply.

For medium-duty trucks, midi buses, heavy-duty trucks, and buses, a test profile determined by the vehicle manufacturer and verified to the vehicle application shall apply.

If vehicle structure or a battery pack or system protection device (e.g. protection frame) is used as part or all of the battery pack or system enclosures, then that vehicle structure can be included in the test.

8.2.3 Requirements

For battery pack or system testing according to 8.2.2 a), during the test and for a 1 h post-test observation period, the DUT shall not exhibit evidence of rupture, fire, or explosion.

For vehicle-based testing according to 8.2.2 b), the relevant requirements of national or regional post-crash regulations shall apply.

8.3 Water immersion

This test simulates water immersion which can occur when a vehicle is flooded.

The lithium-ion specific worst-case scenario of a water immersion for a battery pack or system with clear or salty water is a short circuit (refer to the test in 9.1).

NOTE If an electric system is immersed in conductive water, hazardous gases can be released. It can also cause a loss of electrical isolation. These effects are not unique to lithium-ion battery technology.

8.4 Exposure to fire

8.4.1 Purpose

The purpose of this test is to verify the resistance of the DUT against exposure to fire from outside of the vehicle. In this test, a thermal load which can occur due to a fuel fire underneath the vehicle is simulated. This thermal load 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.

This test is not required when the DUT is installed in the vehicle and mounted such that the lowest surface of the casing of the DUT is more than 1,5 m above the ground.

8.4.2 Test procedure

8.4.2.1 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 battery pack. 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 a battery system 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 can be installed in the relevant vehicle body.

In case the DUT is not 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 diameter 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 battery system, 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 commercial fuel for positive-ignition engines (hereafter called “fuel”) in a pan. The quantity of 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 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 B. 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.

8.4.2.2 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 pan level shall not exceed 2,5 km/h.

8.4.2.3 Exposure to the 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.

8.4.2.4 End of 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. After removal of the pan, the DUT shall be observed until such time as the surface temperature of the DUT has decreased to ambient temperature or has been decreasing for a minimum of 3 h.

8.4.3 Requirements

During the test and until the end of post-test observation according to 8.4.2.4, the DUT shall not exhibit evidence of explosion.

9 Electrical tests

9.1 Short circuit

9.1.1 Purpose

The purpose of the short circuit test is to check the functionality of the overcurrent protection device. This device shall interrupt the short circuit current in order to prevent the DUT from further related severe events caused by an external short circuit.

9.1.2 Test procedure

Conduct the test according to 9.2.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT.

This test applies to battery packs and systems. In all cases the relevant overcurrent protection device as intended by the battery manufacturer shall be included in the DUT.

The test can be conducted using a lower resistance than specified in 9.2.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT, according to agreement between the customer and the supplier.

The test can be conducted at a higher temperature than specified in 9.2.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT, according to agreement between the customer and the supplier.

9.1.3 Requirements

Requirements as given in 5.5 shall apply.

The overcurrent protection function, if any, shall disconnect the short circuit current.

10 System functionality tests

10.1 Overcharge protection

10.1.1 Purpose

The purpose of the overcharge test is to check the functionality of the overcharge protection function. This function shall interrupt the overcharge current in order to protect the DUT from any further related severe events caused by exceeding the upper SOC limit.

10.1.2 Test procedure

Conduct the test according to 9.3.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT.

This test applies to battery packs and systems. In all cases, the relevant overcharge protection device as intended by the battery manufacturer shall be included in the DUT.

The test can be conducted at a higher temperature than specified in 9.3.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT, according to agreement between the customer and the supplier.

A standard cycle according to 6.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT, shall be performed if not inhibited by the DUT after the overcharge.

10.1.3 Requirements

Requirements as given in 5.5 shall apply.

The overcharge protection function, if any, shall interrupt the overcharge current.

10.2 Overdischarge protection

10.2.1 Purpose

The purpose of the overdischarge test is to check the functionality of the overdischarge protection function. This function shall interrupt the overdischarge current in order to protect the DUT from any further related severe events associated with the SOC falling below its lower limit.

10.2.2 Test procedure

Conduct the test according to 9.4.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT.

This test applies to battery packs and systems. In all cases the relevant overdischarge protection device as intended by the battery manufacturer shall be included in the DUT.

The test can be conducted at a higher temperature than specified in 9.4.2 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT, according to agreement between the customer and the supplier.

A standard charge according to 6.2.2.3 of ISO 12405-1:2011 or ISO 12405-2:2012, as appropriate for the DUT, shall be performed if not inhibited by the DUT after the overdischarge.

10.2.3 Requirements

Requirements as given in 5.5 shall apply.

The overdischarge protection function, if any, shall interrupt the overdischarge current.

10.3 Loss of thermal control/cooling

10.3.1 Purpose

The purpose of this test is to verify the ability of the DUT to prevent internal overheating. This test considers also a failure of thermal control or cooling function, if any.

10.3.2 Test procedure

This test applies to battery packs and systems. The relevant thermal protection function as intended by the battery manufacturer shall be in any case part of the DUT.

The DUT shall be at any state of charge, which allows the normal operation of the power train as recommended by the battery manufacturer. The active cooling device, if any, shall be disabled, if possible.

The DUT shall be placed in a convective oven or climatic chamber. The DUT shall be connected to an electric load and shall be continuously charged and discharged with maximum applicable current according to the specifications of the battery manufacturer.

The temperature of the convective oven or climatic chamber shall be gradually increased until the DUT reaches a temperature up to 20 K above the maximum operating temperature specified by the battery manufacturer, or until the rated temperature threshold at which the protection measures would become effective, whichever is lower.

The DUT's temperature shall be monitored by the measurement devices which are integrated in the DUT by the battery manufacturer. If no temperature measurement devices are implemented or their data cannot be monitored externally, the DUT shall be prepared with thermocouples to allow the monitoring of the internal temperatures.

The test shall be terminated if the charge and discharge current is interrupted or reduced by the protective measure of the battery pack or system, or the temperature change of the DUT is less than 4 K within 2 h or 2 h after the DUT reaches the maximum operating temperature specified by the supplier.

NOTE Over-temperature test is also defined in UN ECE R100–02.

10.3.3 Requirements

Requirements as given in 5.5 shall apply.

The thermal control or cooling function, if any, shall interrupt the charge and discharge current.

Annex A
(informative)

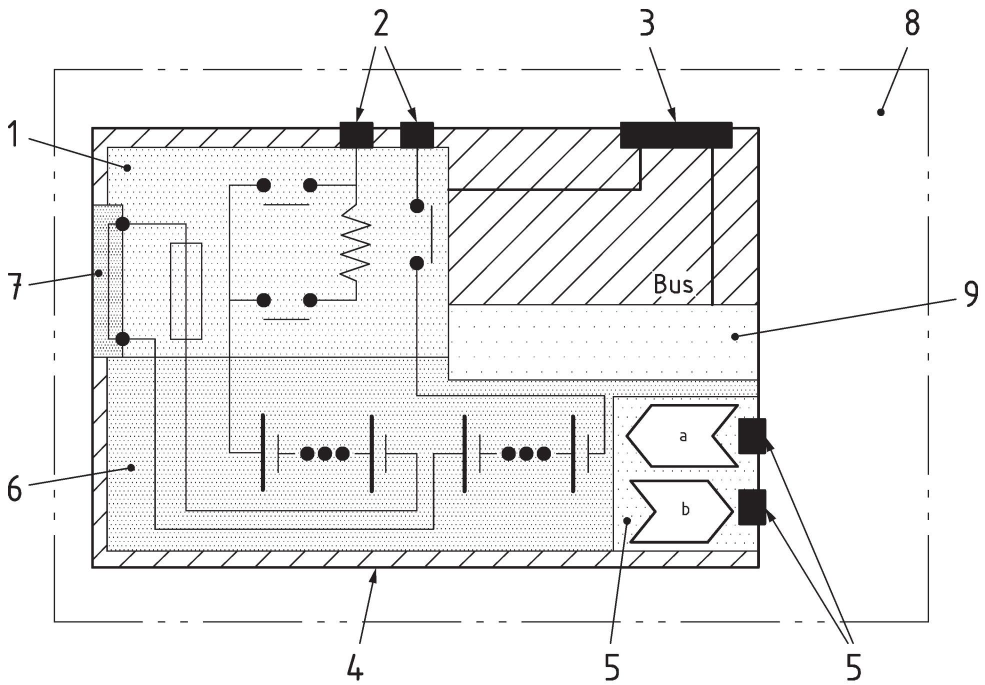
Battery systems and related parts

A.1 General

This Annex provides information on how to distinguish between the battery pack and the battery system.

A.2 Battery pack

Figure A.1 shows a typical configuration of a battery pack.



Key

1 voltage class B electric circuit (connectors, fuses, wiring)

2 voltage class B connections

3 voltage class A connections

4 casing

5 cooling device and connections (optional)

6 cell assembly (cells, sensors, cooling equipment)

7 service disconnect

8 battery pack

9 cell electronics

a In.

b Out.

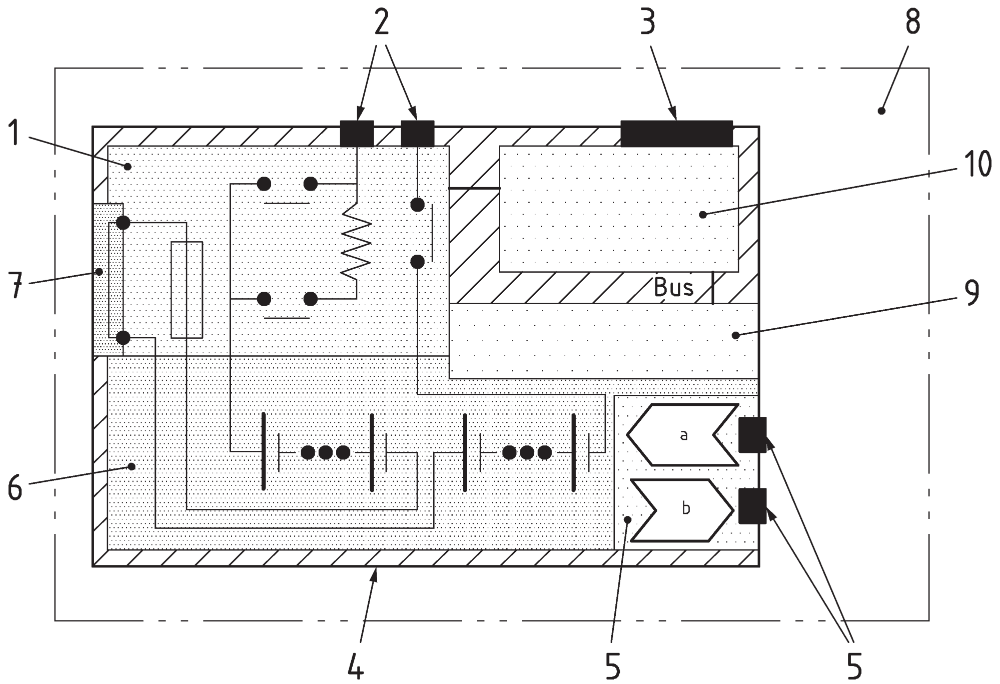
Figure A.1 — Typical configuration of a battery pack

A battery pack represents an energy storage device that includes cells or cell assemblies, cell electronics, voltage class B circuit, and overcurrent shut-off device including electrical interconnections, interfaces for cooling, voltage class B, auxiliary voltage class A, and communication. The voltage class B circuit of the battery pack can include contactors. For a battery pack of 60 V d.c. or higher, a manual shut-off function (service disconnect) can be included. All components are typically placed in a normal-use impact resistance case.

A.3 Battery system

A.3.1 Battery system with integrated battery control unit

Figure A.2 shows a typical configuration of a battery system with integrated battery control unit.



Key

1 voltage class B electric circuit (connectors, fuses, wiring)

2 voltage class B connections

3 voltage class A connections

4 casing

5 cooling device and connections (optional)

6 cell assembly (cells, sensors, cooling equipment)

7 service disconnect

8 battery pack

9 cell electronics

10 battery control unit

a In.

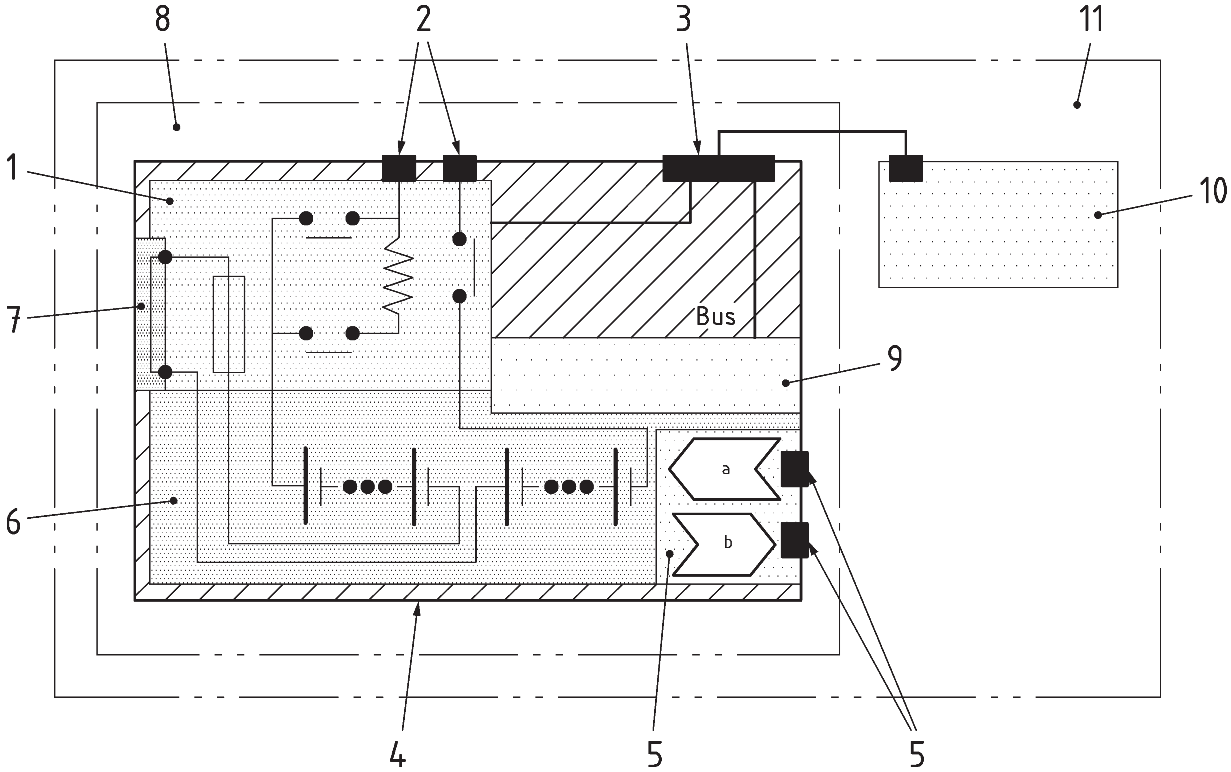
b Out.

Figure A.2 — Typical configuration of a battery system with integrated BCU

A battery system represents an energy storage device that includes cells or cell assemblies, cell electronics, battery control unit, voltage class B circuit with contactors, and overcurrent shut-off device including electrical interconnections, interfaces for cooling, voltage class B, auxiliary voltage class A, and communication. For a battery system of 60 V d.c. or higher, a manual shut-off function (service disconnect) can be included. All components are typically placed in a normal-use impact resistance case. In this example, the battery control unit is integrated inside the normal-use impact resistance case and connected concerning its control functionalities to the battery pack.

A.3.2 Battery system with external battery control unit

Figure A.3 shows the typical configuration of a battery system with external battery control unit.



Key

1 voltage class B electric circuit (connectors, fuses, wiring)

2 voltage class B connections

3 voltage class A connections

4 casing

5 cooling device and connections (optional)

6 cell assembly (cells, sensors, cooling equipment)

7 service disconnect

8 battery pack

9 cell electronics

10 battery control unit

11 battery system

a In.

b Out.

Figure A.3 — Typical configuration of a battery system with external BCU

A battery system represents an energy storage device that includes cells or cell assemblies, cell electronics, battery control unit, voltage class B circuit with contactors, and overcurrent shut-off device including electrical interconnections, interfaces for cooling, voltage class B, auxiliary voltage class A, and communication. For a battery system of 60 V d.c. or higher, a manual shut-off function (service disconnect) can be included. All components are typically placed in a normal-use impact resistance case. In this example, the battery control unit is placed outside the normal-use impact resistance case and connected concerning its control functionalities to the battery pack.

Annex B
(informative)

Description of the screen referenced in 8.4 Exposure to fire

Dimensions in millimetres

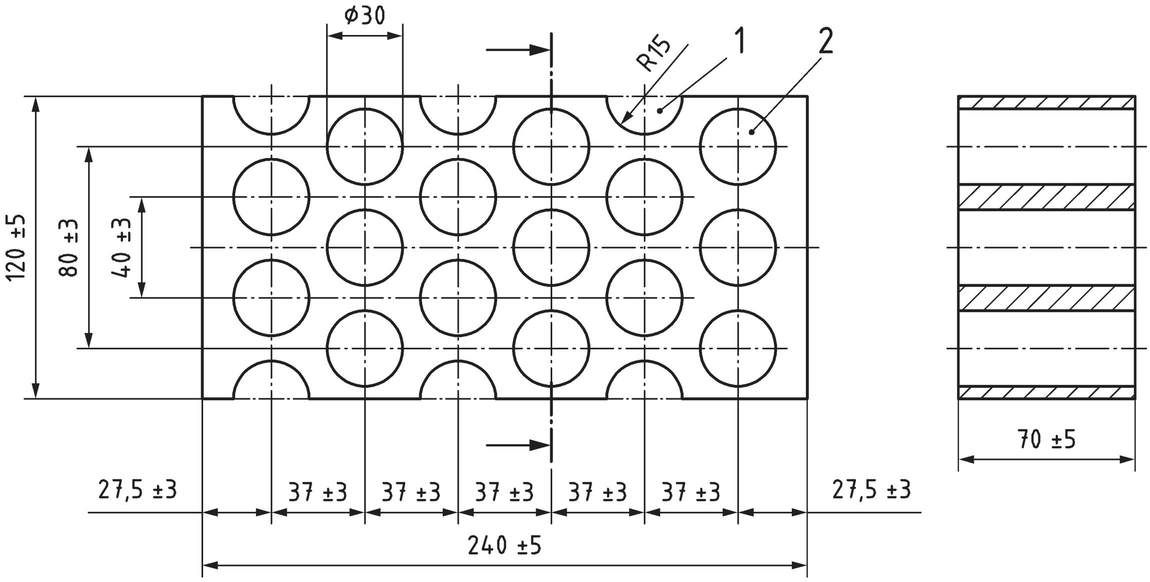


Figure B.1 — Screen for fire protection test

The screen should have the following parameters:

— fire resistance: (Seger-Kegel) SK 30;

— Al_2O_3 content: 30 % to 33 %;

— open porosity (Po): 20 % to 22 % volume;

— density: 1 900 kg/m^3 to 2 000 kg/m^3;

— effective holed area: 44,18 %.

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[4] UN ECE Regulation No. 100 (UN ECE R100), Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train (02 series of amendment or later)

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[6] UN Recommendations on the Transport of Dangerous Goods — Manual of Tests and Criteria — Section 38.3 Lithium metal and lithium ion batteries

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