INTERNATIONAL STANDARD

ISO 12405-2

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

Part 2: High-energy applications

Véhicules routiers à propulsion électrique — Spécifications d'essai pour des installations de batterie de traction aux ions lithium —

Partie 2: Applications à haute énergie

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Foreword

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

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

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

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

ISO 12405-2 was prepared by Technical Committee 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*

The following part is under preparation:

— *Part 3: Safety performance requirements*

Introduction

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

ISO 12405 provides specific test procedures for lithium-ion battery packs and systems specially developed for propulsion of road vehicles. It specifies such tests and related requirements to ensure that a battery pack or system is able to meet the specific needs of the automobile industry. It enables vehicle manufacturers to choose test procedures to evaluate the characteristics of a battery pack or system for their specific requirements.

A coordination of test specifications for battery cells, packs and systems for automotive application is necessary for practical usage of standards.

Specifications for battery cells are given in IEC 62660-1 and IEC 62660-2.

Some tests as prescribed within this specification are based on existing specifications: *USABC, EUCAR, FreedomCar* and other sources.

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

Part 2: High-energy applications

1 Scope

ISO 12405 specifies test procedures for lithium-ion battery packs and systems to be used in electrically propelled road vehicles.

The specified test procedures enable the user of ISO 12405 to determine the essential characteristics of performance, reliability and abuse of lithium-ion battery packs and systems. They also assist the user in comparing the test results achieved for different battery packs or systems.

Therefore the objective of ISO 12405 is to specify standard test procedures for the basic characteristics of performance, reliability and abuse of lithium-ion battery packs and systems.

ISO 12405 enables the setting up of a dedicated test plan for an individual battery pack or system subject to an agreement between customer and supplier. If required, the relevant test procedures and/or test conditions of lithium-ion battery packs and systems can be selected from the standard tests provided in ISO 12405 to configure a dedicated test plan.

This part of ISO 12405 specifies the tests for high-energy battery packs and systems.

NOTE 1 Typical applications for high-energy battery packs and systems are battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV).

NOTE 2 Testing on cell level is specified in IEC 62660-1 and IEC 62660-2.

2 Normative references

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

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

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

ISO 16750-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 16750-3, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 3: Mechanical loads*

ISO 16750-4, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 4: Climatic loads*

IEC 60068-2-30, *Environmental testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-47, *Environmental testing — Part 2-47: Tests — Mounting of specimens for vibration, impact and similar dynamic tests*

IEC 60068-2-64, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and guidance*

3 Terms and definitions

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

3.1
battery control unit
BCU
electronic device that controls or manages or detects or calculates electric and thermal functions of the battery system and that provides communication between the battery system and other vehicle controllers

NOTE See also 5.5.1 for further explanation.

3.2
battery pack
mechanical assembly comprising battery cells and retaining frames or trays, and possibly components for battery management

NOTE See 5.4 and A.2 for further explanation.

3.3
battery system
energy storage device that includes cells or cell assemblies or battery pack(s) as well as electrical circuits and electronics

NOTE 1 See 5.5.2, 5.5.3, A.3.1 and A.3.2 for further explanation. Battery system components can also be distributed in different devices within the vehicle.

NOTE 2 Examples of electronics are the BCU and contactors.

3.4
capacity
total number of ampere hours that can be withdrawn from a battery under specified conditions

3.5
cell electronics
electronic device that collects and possibly monitors thermal and electric data of cells or cell assemblies and contains electronics for cell balancing, if necessary

NOTE The cell electronics may include a cell controller. The functionality of cell balancing may be controlled by the cell electronics or it may be controlled by the BCU.

3.6
customer
party that is interested in using the battery pack or system and therefore orders or performs the test

EXAMPLE vehicle manufacturer

3.7
device under test
DUT
battery pack or battery system

3.8
energy density
amount of stored energy related to the battery pack or system volume

NOTE 1 The battery pack or system includes the cooling system, if any, to the point of a reversible attachment of the coolant lines or air ducts, respectively.

NOTE 2 Energy density is expressed in watt hours per litre (W·h/l).

3.9
energy round trip efficiency
ratio of the net d.c. energy delivered by a DUT during a discharge test to the total d.c. energy required to restore the initial SOC by a standard charge

NOTE The net d.c. energy is expressed as watt hours (W·h) discharge and the total d.c. energy is expressed as watt hours (W·h) charge.

3.10
high-energy application
characteristic of device or application, for which the numerical ratio between maximum allowed electric power output and electric energy output at a 1C discharge rate at RT for a battery pack or system is typically lower than 10

NOTE Typically high-energy battery packs and systems are designed for applications in BEVs.

NOTE 2 The allowed electric power output is expressed as power in watts (W) and the electric energy output is expressed as energy in watt hours (W·h).

3.11
high-power application
characteristic of device or application, for which the numerical ratio between maximum allowed electric power output and electric energy output at a 1C discharge rate at RT for a battery pack or system is typically equal to or higher than 10

NOTE 1 Typically high-power battery packs and systems are designed for applications in HEVs and FCVs.

NOTE 2 The allowed electric power output is expressed as power in watts (W) and the electric energy output is expressed as energy in watt hours (W·h).

3.12
maximum working voltage
highest value of a.c. voltage (r.m.s) or of d.c. voltage which may occur in an electric system under any normal operating conditions according to the manufacturer's specifications, disregarding transients

3.13
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, and discharge cut-off voltage

3.14
room temperature
RT
temperature of (25 ± 2) °C

3.15
sign of battery current
discharge current is specified as positive and the charge current as negative

3.16
specific energy
amount of stored energy related to the battery pack or system mass

NOTE 1 The battery pack or system shall include the cooling system, if any, to the point of a reversible attachment of the coolant lines or air ducts, respectively. For liquid cooled systems the coolant mass inside the battery pack or system shall be included.

NOTE 2 Specific energy is expressed in watt hours per kilogram (W·h/kg).

3.17
state of charge
SOC
available capacity in a battery pack or system

NOTE State of charge is expressed as a percentage of rated capacity.

3.18
standard charge (SCH) for top off
additional charge which eliminates possible SOC reduction after SCH at RT followed by thermal equilibration at a different temperature

3.19
supplier
party that provides battery systems and packs

EXAMPLE battery manufacturer

3.20
voltage class A
classification of an electric component or circuit with a maximum working voltage of $0 < U \leq 30$ V a.c. r.m.s. or $0 < U \leq 60$ V d.c.

NOTE For more details, see ISO 6469-3.

3.21
voltage class B
classification of an electric component or circuit with a maximum working voltage of $30 < U \leq 1\,000$ V a.c. r.m.s. or $60 < U \leq 1\,500$ V d.c.

NOTE For more details, see ISO 6469-3.

4 Symbols and abbreviated terms

a.c.	alternating current
BCU	battery control unit
BEV	battery electric vehicle
BOL	beginning of life
C	capacity, expressed in ampere hours (A·h)
nC	current rate equal to n times the one hour discharge capacity expressed in ampere (e.g. 3C is equal to three times the 1 h current discharge rate, expressed in ampere)
d.c.	direct current
DUT	device under test
EODV	end of discharge voltage
EUCAR	European Council for Automotive Research
EV	electric vehicle
FCV	fuel cell vehicle
HEV	hybrid electric vehicle

$I_{c,max}$	maximum continuous charge current specified by the manufacturer for energy efficiency at fast charging testing
$I_{d,max}$	maximum continuous discharge current specified by the manufacturer for energy and capacity testing
$I_{dp,max}$	maximum discharge pulse current specified by the manufacturer for power, internal resistance and energy efficiency testing
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
Li	lithium
Li-ion	lithium-ion
OCV	Open Circuit Voltage
PHEV	plug-in hybrid electric vehicle
PNGV	partnership for a new generation of vehicles
PSD	power spectral density
RESS	rechargeable energy storage system
r.m.s.	root mean square
RT	room temperature (25 ± 2) °C
SC	standard cycle
SCH	standard charge
SDCH	standard discharge
SOC	state of charge
USABC	United States Advanced Battery Consortium
η	efficiency

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:

— The electrical safety design shall be approved according 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, communication) shall be delivered together with the DUT.

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

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).

If not otherwise specified, 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.

If not otherwise specified, each charge and each SOC change shall be followed by a rest period of 30 min.

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.

NOTE If agreed between customer and supplier, for a battery pack or system consisting of more than one subset the tests may be applied on such subsets.

5.2 Test sequence plan

The test sequence for an individual battery pack or system, or a battery pack subsystem shall be based on agreement between customer and supplier with consideration of tests in 5.3.

An example for a list of test conditions to be agreed between customer and supplier is provided in Table C.1.

5.3 Tests

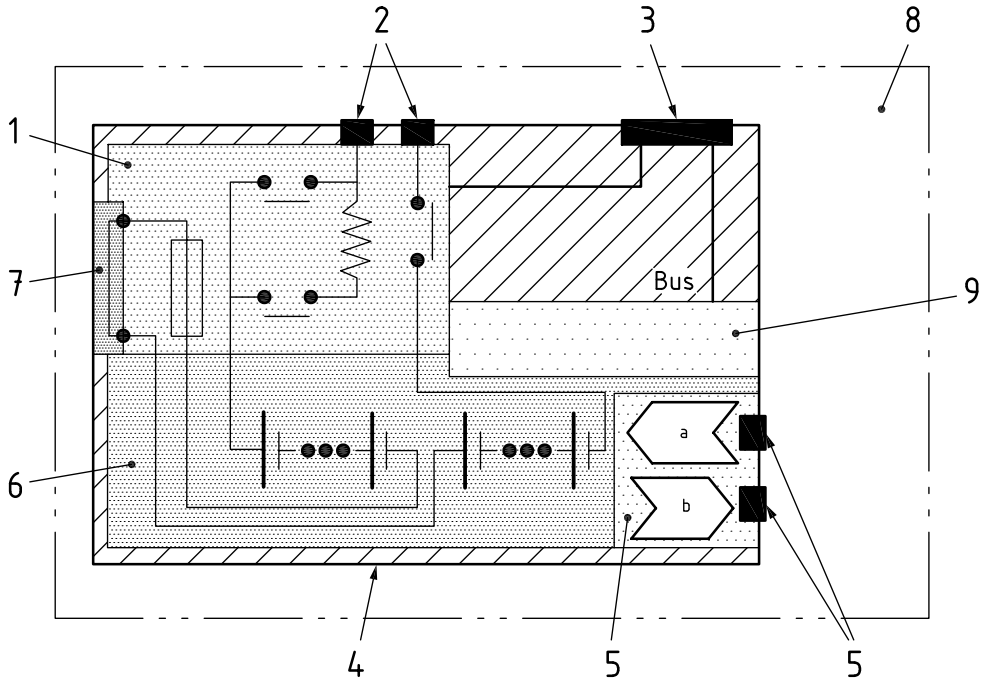
An overview about the tests is given in Figure 1, where the references to the specific clauses are also given.

Overview of tests

General tests (Clause 6)	Performance tests (Clause 7)	Reliability tests (Clause 8)	Abuse tests (Clause 9)
Pre-conditioning cycles (Clause 6.1)	Energy and capacity at RT (Clause 7.1)	Dewing (Clause 8.1)	Short circuit protection (Clause 9.2)
Standard cycle (Clause 6.2)	Energy and capacity at different temperature and discharge rates (Clause 7.2)	Thermal shock cycling (Clause 8.2)	Overcharge protection (Clause 9.3)
Standard discharge (Clause 6.2.2.2)	Power and internal resistance (Clause 7.3)	Vibration (Clause 8.3)	Overdischarge protection (Clause 9.4)
Standard charge (Clause 6.2.2.3)	Energy efficiency at fast charging (Clause 7.4)	Mechanical shock (Clause 8.4)	
	No load SOC loss (Clause 7.5)		
	SOC loss at storage (Clause 7.6)		
	Cycle life (Clause 7.7)		

Figure 1 — Test plan – overview

5.4 Battery pack - typical configuration



Key

1 voltage class B electric circuit (contactors, fuses, wiring)
2 voltage class B connections
3 voltage class A connections
4 normal use impact-resistant case
5 cooling device and connections
6 cell assembly
7 service disconnect
8 battery pack
9 cell electronics
a In.
b Out.

Figure 2 — Typical configuration of battery pack

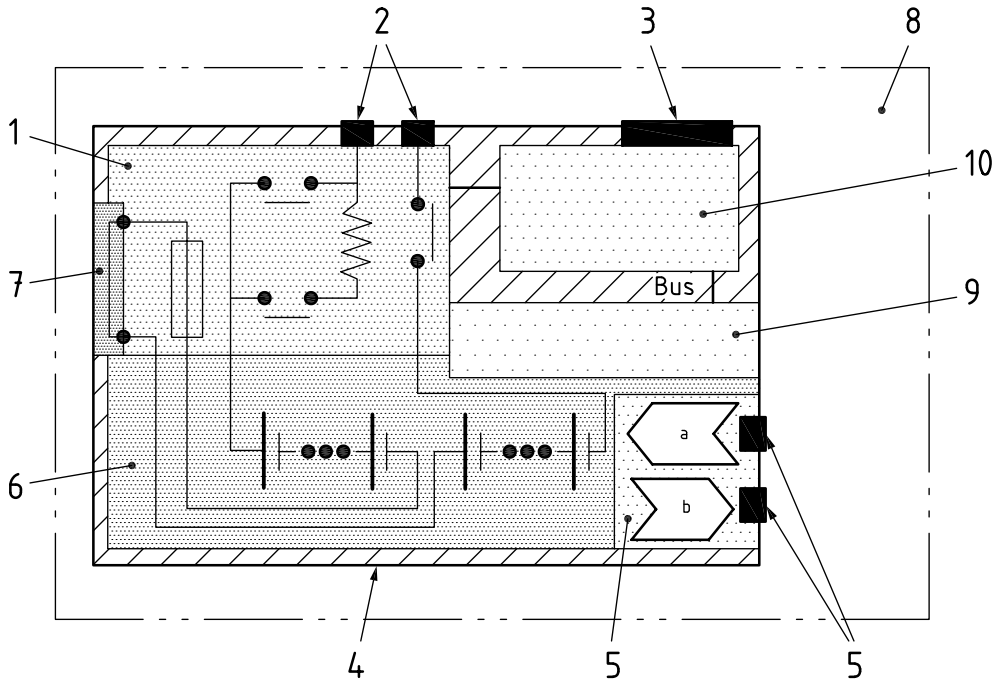
A battery pack represents an energy storage device that includes cells or cell assemblies, cell electronics, voltage class B circuit and overcurrent shut-off device including electrical interconnections, interfaces for cooling, voltage class B, auxiliary voltage class A and communication. The voltage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

5.5 Battery system - typical configuration

5.5.1 BCU

The BCU calculates state-of-charge and state-of-health and provides battery system operational limits to the vehicle management unit. The BCU may have direct access to the main contactors of the battery system in order to interrupt the voltage class B circuit under specified conditions, e.g. overcurrent, over voltage, low voltage, high temperature. The BCU may vary in design and implementation, it may be a single electronic unit integrated into the battery system or it may be placed outside the battery pack and connected via a communication bus or input/output lines to the battery pack. The BCU functionalities may be integrated functions of one or more vehicle control units.

5.5.2 Battery system with integrated battery control unit (BCU)



Key

1 voltage class B electric circuit (contactors, fuses, wiring)
2 voltage class B connections
3 voltage class A connections
4 normal use impact-resistant case
5 cooling device and connections
6 cell assembly
7 service disconnect
8 battery pack
9 cell electronics
10 battery control unit
a In.
b Out.

Figure 3 — Typical configuration of 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) may be included. All components are typically placed in a normal use impact-resistant case. In this example, the battery control unit is integrated inside the normal use impact-resistant case and its control functionalities are connected to the battery pack.