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Safety of primary lithium batteries

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Battery Association of Japan (BAJ)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS C 8513:2015**), which has been technically revised.

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Safety of primary lithium batteries

Introduction

This Japanese Industrial Standard has been prepared based on **IEC 60086-4** : 2019, Edition 5, with some modifications of the technical contents to reflect the unique condition in Japan.

The dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.

NOTE 1 Primary lithium batteries herein refer to those of electrochemical systems of letters B, C, E, F, G, W and Y given in Table 1 of **JIS C 8500**.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

IEC 60086-4 : 2019 *Primary batteries — Part 4 : Safety of lithium batteries* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 8500 *Primary batteries — General*

NOTE Corresponding International Standard : IEC 60086-1 *Primary batteries — Part 1 : General*

JIS C 8515 *Primary batteries — Physical and electrical specifications*

NOTE Corresponding International Standard : IEC 60086-2 *Primary batteries — Part 2 : Physical and electrical specifications*

JIS Z 9101 *Graphical symbols — Safety colours and safety signs — Part 1 : Design principles for safety signs and safety markings*

NOTE Corresponding International Standard : ISO 3864-1 *Graphical symbols — Safety colours and safety signs — Part 1 : Design principles for safety signs and safety markings*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions apply.

3.1

battery

one or more cells electrically connected and fitted in a case, with terminals, markings and protective devices etc., as necessary for use

[SOURCE : **IEV482-01-04**, modified (description changed for clarification)]

3.2

cell

basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy

[SOURCE : **IEV482-01-01**]

3.3

coin (cell or battery)

small round cell or battery where the overall height is less than the diameter, containing nonaqueous electrolyte

[SOURCE : **IEV482-02-40**, modified (the word “battery” added, the note replaced with a different note)]

3.4

component cell

cell contained in a battery

3.5

cylindrical (cell or battery)

round cell or battery in which the overall height is equal to or greater than the diameter

[SOURCE : **IEV482-02-39**, modified (the word “battery” added)]

3.6

depth of discharge, DOD

percentage of the capacity discharged from a cell or battery under the conditions specified by the manufacturer to the nominal capacity

3.7

fully discharged

state of a cell or battery at 100 % depth of discharge

3.8

harm

injury or damage to the health of people, or damage to property or the environment

(SOURCE : JIS Z 8051 : 2015, 3.1)

3.9

~~(Entry deleted as unnecessary in JIS.)~~

3.10

intended use

use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

(SOURCE : JIS Z 8051 : 2015, 3.6)

3.11

large battery

battery with a gross mass of more than 12 kg

3.12

large cell

cell with a gross mass of more than 500 g

3.13

~~(Entry deleted as unnecessary in JIS.)~~

3.13A

primary lithium batteries

batteries containing a non-aqueous electrolyte and a negative electrode of lithium or containing lithium

(SOURCE : IEV482-01-06)

3.14

nominal voltage

suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system

(SOURCE : IEV482-03-31)

3.15

open-circuit voltage, OCV

voltage across the terminals of a cell or battery when no external current is flowing

[SOURCE : IEV482-03-32, modified (the abbreviation added, and description

changed for clarification)]

3.16

(Entry deleted as unnecessary in **JIS**.)

3.16A

non-circular battery

cell or battery having a cross-section other than circular

NOTE Category 6 batteries specified in **JIS C 8515**.

3.17

protective devices

devices such as fuses, diodes or other electric or electronic current limiters designed to interrupt the current flow, block the current flow in one direction or limit the current flow in an electrical circuit

3.18

(Entry deleted as unnecessary in **JIS**.)

3.18A

nominal capacity

capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

NOTE This term replaces “rated capacity” given in the corresponding International Standard, to which it has an equal definition.

3.19

reasonably foreseeable misuse

use of a battery in a way not intended by the supplier, but which may result from readily predictable human behaviour

[SOURCE : **JIS Z 8051** : 2015, 3.7, modified (limitation to battery, removal of NOTE 1 and NOTE 2)]

3.20

risk

combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: **JIS Z 8051** : 2015, 3.9, modified (removal of NOTE)]

3.21

safety

freedom from risk which is not tolerable

(SOURCE : **JIS Z 8051** : 2015, 3.14)

3.22

undischarged

state of a primary cell or battery at 0 % depth of discharge

4 Requirements for safety

4.1 Design

Lithium batteries are categorized by their chemical composition (anode, cathode, electrolyte), internal construction (bobbin, spiral) and are available in cylindrical, coin and non-circular configurations. It is necessary to consider all relevant safety aspects at the battery design stage, recognizing the fact that they can differ considerably, depending on the internal construction, configuration, capacity, etc.

The following design concepts for safety are common to all lithium batteries:

- a) Abnormal temperature rise above the critical value defined by the manufacturer shall be prevented by design.
- b) Temperature increases in the battery shall be controlled by a design which limits current flow.
- c) Lithium batteries shall be designed to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport, intended use and reasonably foreseeable misuse, e.g. by having a gas-releasing vent.

See Annex A for guidelines for the achievement of safety of lithium batteries.

4.2 Quality plan

The manufacturer shall prepare and implement a quality plan defining the procedures for the inspection of materials, components, cells and batteries during the course of manufacture, to be applied to the total process of producing a specific type of battery. Manufacturers should understand their process capabilities and should institute the necessary process controls as they relate to product safety.

5 Test items and sampling

5.1 Validity of testing

Lithium batteries shall be subjected to the tests, as required in this Standard. Testing remains valid until a design change or requirement revision has been made. Re-testing is required when :

- a) a battery specification changes by more than 0.1 g or 20 % mass, whichever is greater, for the cathode, anode or electrolyte;
- b) a battery specification change would lead to a failure of any of the tests;
- c) there is an addition of new tests or requirements; or
- d) there is a requirement change that would lead to a failure of any of the tests.

5.2 Test samples

Samples should be drawn from production lots in accordance with accepted statistical methods. The number of test samples is given in Table 1. The same test cells and batteries are used for tests A to E in sequence. New test cells and batteries are required for each of tests F to M.

Table 1 Number of test samples

Tests	Discharge state	Cells and single cell batteries ^{a)}	Multi-cell batteries
Tests A to E	Undischarged	10	4
	Fully discharged	10	4
Test F or G	Undischarged	5	5 component cells
	Fully discharged	5	5 component cells
Test H	Fully discharged	10	10 component cells
Tests I to K	Undischarged	5	5
Test L	Undischarged	20 ^{b)}	—
Test M	50 % predischarged	20 ^{c)}	—
	75 % predischarged	20 ^{d)}	—
— : not specified. NOTE 1 The content has been moved to Note ^{b)} in accordance with JIS layout rules. NOTE 2 The content has been moved to Note ^{c)} in accordance with JIS layout rules. NOTE 3 The content has been moved to Note ^{d)} in accordance with JIS layout rules. Notes ^{a)} Batteries with all of their component cells tested do not require re-testing unless a change has been made that could result in a failure of any of the tests. ^{b)} Four batteries connected in series with one of the four batteries reversed (5 sets). ^{c)} Four batteries connected in series, one of which is 50 % predischarged (5 sets). ^{d)} Four batteries connected in series, one of which is 75 % predischarged (5 sets).			

6 Testing and requirements

6.1 General

6.1.1 Test application matrix

Applicability of test methods to test cells and batteries is shown in Table 2.

Table 2 Test application matrix

Form	Applicable tests												
	Intended use tests				Reasonably foreseeable misuse tests								
	A	B	C	D	E	F	G	H	I	J	K	L	M
s	○	○	○	○	○	○ ^{a)}	○ ^{a)}	○	○	○	○	○ ^{b)}	○ ^{c)}
m	○	○	○	○	○	○ ^{a) d)}	○ ^{a) d)}	○ ^{d)}	○	○	○	—	—
Intended use tests A : Altitude B : Thermal cycling C : Vibration D : Shock Reasonably foreseeable misuse tests E : External short-circuit F : Impact G : Crush H : Forced discharged I : Abnormal charging J : Free fall K : Thermal abuse L : Incorrect installation M : Overdischarge Form s : cell or single cell battery m : multi-cell battery Applicability ○ : applicable — : not applicable													
Notes ^{a)} Test F is applicable to cylindrical batteries of diameter 18 mm or greater, and Test G, to non-circular batteries, coin batteries, and cylindrical batteries of diameter under 18 mm. ^{b)} Only applicable to CR17345 (CR123A), CR15H270 (CR2) and similar type batteries of a spiral construction that are for general consumer use and could be installed incorrectly and charged. ^{c)} Only applicable to CR17345 (CR123A), CR15H270 (CR2) and similar type batteries of a spiral construction that are for general consumers use and could be mixed with old batteries, causing overdischarge. ^{d)} Applicable to the component cells.													

6.1.2 Cautionary notice

Warning These tests call for the use of procedures which can result in injury if adequate precautions are not taken. It has been assumed in the drafting of these tests that their execution is undertaken by appropriately qualified and experienced technicians using adequate protection.

6.1.3 Ambient temperature

Unless otherwise specified, the tests shall be carried out at an ambient temperature of $20\text{ °C} \pm 5\text{ °C}$.

6.1.4 Parameter measurement tolerances

The overall accuracy of controlled or measured values, relative to the specified or actual parameters, shall be within the following tolerances.

These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

- a) ± 1 % for voltage;
- b) ± 1 % for current;
- c) ± 2 °C for temperature;
- d) ± 0.1 % for time;
- e) ± 1 % for dimensions;
- f) ± 1 % for capacity.

6.1.5 Predischage

Where a test requires predischage, the test cells or batteries shall be discharged to the respective depth of discharge on a resistive load with which the nominal capacity is obtained or at a current specified by the manufacturer.

6.1.6 Additional cells or batteries

Where additional cells or batteries are required to perform a test, they shall be of the same type and, preferably, from the same production lot as the test cell or battery.

6.2 Evaluation of test criteria

6.2.1 Short-circuit

A short-circuit is considered to have occurred during a test if the open-circuit voltage of the cell or battery immediately after the test is less than 90 % of its voltage prior to the test. This requirement is not applicable to test cells or batteries in fully discharged states.

6.2.2 Excessive temperature rise

An excessive temperature rise is considered to have occurred during a test if the external case temperature of the test cell or battery rises above 170 °C.

6.2.3 Leakage

Leakage is considered to have occurred during a test if there is visible escape of electrolyte, gas or other material from the test cell or battery, or the loss of material (except battery casing, handling devices or labels) from the test cell or battery such that the mass loss exceeds the limits in Table 3.

In order to quantify mass loss Δ_m/m , the following equation is provided :

$$\Delta_m/m = \frac{m_1 - m_2}{m_1} \times 100\%$$

where,

- m_1 : mass before a test (g)
- m_2 : mass after that test (g)
- Δ_m : mass loss of battery (g)

Table 3 Mass loss limits

Mass of battery m g	Limit of mass loss $\Delta m/m$ %
$m < 1$	0.5
$1 \leq m \leq 75$	0.2
$m > 75$	0.1

6.2.4 Venting

Venting is considered to have occurred if, during a test, an excessive build up of internal gas pressure escapes from a cell or battery through a pressure relief feature designed for this purpose. This gas may include entrapped materials.

6.2.5 Fire

A fire is considered to have occurred if, during a test, flames are emitted from the test cell or battery.

6.2.6 Rupture

A rupture is considered to have occurred if a cell container or battery case has mechanically failed (but without completely losing its original form), resulting in expulsion of gas or spillage of liquids but not forcible ejection of solid materials.

6.2.7 Explosion

An explosion is considered to have occurred if a cell container or battery case violently cracks open into several pieces, with enough energy to forcibly eject the solid components to a distance of 250 mm or more from the centre of the battery.

NOTE This Standard defines rupture by the distance of ejected solid components from the centre of the battery.

6.3 Tests and requirements — Overview

This document provides safety tests for intended use (tests A to D) and reasonably foreseeable misuse (tests E to M).

Table 4 contains an overview of the tests and requirements for intended use and reasonably foreseeable misuse.

Table 4 Tests and requirements

Tests			Requirements
Intended use tests	A	Altitude	NC, NL, NV, NF, NR, NE
	B	Thermal cycling	NC, NL, NV, NF, NR, NE
	C	Vibration	NC, NL, NV, NF, NR, NE
	D	Shock	NC, NL, NV, NF, NR, NE
Reasonably foreseeable misuse tests	E	External short-circuit	NT, NF, NR, NE
	F	Impact	NT, NF, NE
	G	Crush	NT, NF, NE
	H	Forced discharge	NF, NE
	I	Abnormal charging	NF, NE
	J	Free fall	NV, NF, NE
	K	Thermal abuse	NF, NE
	L	Incorrect installation	NF, NE
	M	Overdischarge	NF, NE
Tests A through E shall be conducted in sequence on the same cell or battery. Tests F through M shall each be conducted on a new cell or battery. Tests F and G are provided as alternatives. Only one of them shall be conducted.			
Key NC : No short-circuit NT : No excessive temperature rise NL : No leakage NV : No venting NF : No fire NR : No rupture NE : No explosion See 6.2 for a detailed description of the test criteria.			

6.4 Tests for intended use

6.4.1 Test A : Altitude

This test shall be as follows.

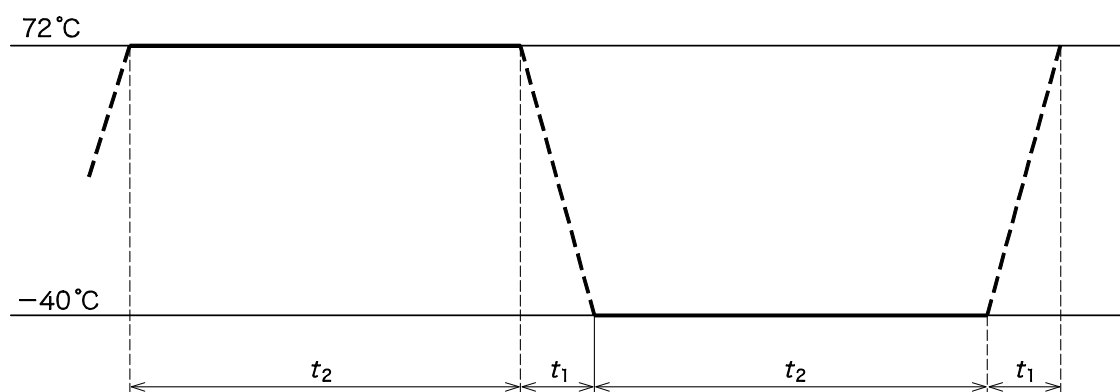
- Purpose** This test simulates air transport under low pressure conditions.
- Test procedure** Test cells or batteries shall be stored at a pressure of 11.6 kPa or less for at least 6 h at ambient temperature of $20\text{ °C} \pm 5\text{ °C}$.
- Requirements** There shall be no short-circuit, no leakage, no venting, no fire, no rupture and no explosion during this test.

6.4.2 Test B : Thermal cycling

This test shall be as follows.

- Purpose** This test assesses cell or battery seal integrity and that of their internal electrical connections.
- Test procedure** The test shall be conducted according to the following cycle (see Figure 1) using the test cells or batteries previously subjected to the test A (altitude).

- 1) Test cells or batteries shall be stored in a test chamber maintained at a test temperature of 72 °C for at least 6 h (t_2). For large cells or batteries, t_2 shall be at least 12 h.
- 2) The procedure in 1) shall be followed by storage at a test temperature of −40 °C for at least 6 h (t_2) after lowering the temperature from 72 °C within 30 min (t_1). For large cells or batteries, t_2 shall be at least 12 h.
- 3) The test temperature shall be raised to 72 °C within 30 min (t_1).
- 4) For each test cell and battery, repeat this procedure [1) to 3)] nine times (a total of ten times).
- 5) This is then followed by storage at 20 °C ± 5 °C for at least 24 h.



$t_1 \leq 30 \text{ min}$

$t_2 \geq 6 \text{ h}$ (12 h for large cells or batteries)

NOTE The figure shows one of ten cycles

Figure 1 Thermal cycling procedure

- c) **Requirements** There shall be no short-circuit, no leakage, no venting, no fire, no rupture and no explosion during this test.

6.4.3 Test C : Vibration

This test shall be as follows.

- a) **Purpose** This test simulates vibration during transport. The test condition is based on the range of vibrations as given by International Civil Aviation Organization (ICAO).

NOTE See **JIS C 60068-2-6** for matters related to this test.

- b) **Test procedure** The test shall be conducted according to the following procedure (see Table 5) using the test cells or batteries previously subjected to the test A (altitude) and test B (thermal cycling).

- 1) Test cells or batteries shall be firmly secured to the platform of the vibration machine without distorting them and in such a manner as to faithfully transmit the