



BSI Standards Publication

<http://www.china-gauges.com/>

**Secondary cells and
batteries containing alkaline
or other non-acid electrolytes
— Safety requirements for
portable sealed secondary
cells, and for batteries made
from them, for use in
portable applications**

National foreword

This British Standard is the UK implementation of EN 62133:2013. It is identical to IEC 62133:2012, incorporating corrigendum June 2013. It supersedes BS EN 62133:2003 which is withdrawn.

IEC corrigendum June 2013 replaces the text of 10.1 Cell marking.

The UK participation in its preparation was entrusted by Technical Committee PEL/21, Secondary cells and batteries, to Subcommittee PEL/21/1, Secondary cells and batteries containing alkaline and other non-acidic electrolytes.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2013.

Published by BSI Standards Limited 2013

ISBN 978 0 580 63064 4

ICS 29.220.30

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2013.

Amendments/corrigenda issued since publication

| Date | Text affected |
|------|---------------|
|------|---------------|

English version

Secondary cells and batteries containing alkaline or other non-acid electrolytes
Safety requirements for portable sealed secondary cells, and for batteries made from them for use in portable applications
(IEC 62133:2012)

Accumulateurs alcalins et autres accumulateurs à électrolyte non acide - Exigences de sécurité pour les accumulateurs portables étanches, et pour les batteries qui en sont constituées, destinés à l'utilisation dans des applications portables
(CEI 62133:2012)

Akkumulatoren und Batterien mit alkalischen Oder anderen nicht säurehaltigen Elektrolyten - Sicherheitsanforderungen für tragbare gasdichte Akkumulatoren und daraus hergestellte Batterien für die Verwendung in tragbaren Geräten
(IEC 62133:2012)

This European Standard was approved by CENELEC on 2013-01-10. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Mamix 17, B -1000 Brussels

Foreword

The text of document 21A/503/FDIS, future edition 2 of IEC 62133, prepared by SC 21 A, "Secondary cells and batteries containing alkaline or other non-acid electrolytes", of IECTC21, "Secondary cells and batteries" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62133:2013.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-10-10
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2016-01-10

This document supersedes EN 62133:2003.

EN 62133:2013 includes the following significant technical changes with respect to EN 62133:2003:

- update of assembly of cells into batteries (5.5);
- addition of design recommendations for lithium system only (5.6.2);
- separation of nickel systems and lithium systems (Clause 6);
- addition of specific requirements and tests for lithium systems (Clause 8);
- addition of charging of secondary lithium-ion cells for safe use (Annex A).

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

Endorsement notice

The text of the International Standard IEC 62133:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

| | | |
|------------------|------|--------------------------------|
| IEC 60051 series | NOTE | Harmonized in EN 60051 series. |
| IEC 60664 series | NOTE | Harmonized in EN 60664 series. |
| IEC 61434 | NOTE | Harmonized as EN 61434. |
| IEC 62281 | NOTE | Harmonized as EN 62281. |

Annex ZA
(normative)

**Normative references to international publications
with their corresponding European publications**

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.

NOTE When an International publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

| <u>Publication</u> | <u>Year</u> | <u>Title</u> | <u>EN/HD</u> | <u>Year</u> |
|--------------------|-------------|---|--------------|-------------|
| I EC 60050-482 | - | International Electrotechnical Vocabulary (IEV) - Part 482: Primary and secondary cells and batteries | - | - |
| IEC 61951-1 | - | Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 1: Nickel-cadmium | EN 61951-1 | - |
| IEC 61951-2 | - | Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 2: Nickel-metal hydride | EN 61951-2 | - |
| IEC 61960 | - | Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications | EN 61960 | - |
| ISO/IEC Guide 51 | - | Safety aspects - Guidelines for their inclusion - in standards | - | - |

CONTENTS

| | | |
|-------|--|----|
| 1 | Scope..... | 6 |
| 2 | Normative references..... | 6 |
| 3 | Terms and definitions..... | 6 |
| 4 | Parameter measurement tolerances..... | 8 |
| 5 | General safety considerations..... | 8 |
| 5.1 | General..... | 8 |
| 5.2 | Insulation and wiring..... | 9 |
| 5.3 | Venting..... | 9 |
| 5.4 | Temperature/voltage/current management..... | 9 |
| 5.5 | Terminal contacts..... | 9 |
| 5.6 | Assembly of cells into batteries..... | 9 |
| 5.6.1 | General..... | 9 |
| 5.6.2 | Design recommendation for lithium systems only..... | 10 |
| 5.7 | Quality plan..... | 10 |
| 6 | Type test conditions..... | 10 |
| 7 | Specific requirements and tests (nickel systems)..... | 11 |
| 7.1 | Charging procedure for test purposes..... | 11 |
| 7.2 | Intended use..... | 12 |
| 7.2.1 | Continuous low-rate charging (cells)..... | 12 |
| 7.2.2 | Vibration..... | 12 |
| 7.2.3 | Moulded case stress at high ambient temperature (batteries)..... | 12 |
| 7.2.4 | Temperature cycling..... | 13 |
| 7.3 | Reasonably foreseeable misuse..... | 13 |
| 7.3.1 | Incorrect installation (cells)..... | 13 |
| 7.3.2 | External short circuit..... | 14 |
| 7.3.3 | Free fall..... | 14 |
| 7.3.4 | Mechanical shock (crash hazard)..... | 14 |
| 7.3.5 | Thermal abuse (cells)..... | 15 |
| 7.3.6 | Crushing of cells..... | 15 |
| 7.3.7 | Low pressure (cells)..... | 15 |
| 7.3.8 | Overcharge..... | 15 |
| 7.3.9 | Forced discharge (cells)..... | 16 |
| 8 | Specific requirements and tests (lithium systems)..... | 16 |
| 8.1 | Charging procedures for test purposes..... | 16 |
| 8.1.1 | First procedure..... | 16 |
| 8.1.2 | Second procedure..... | 16 |
| 8.2 | Intended use..... | 17 |
| 8.2.1 | Continuous charging at constant voltage (cells)..... | 17 |
| 8.2.2 | Moulded case stress at high ambient temperature (battery)..... | 17 |
| 8.3 | Reasonably foreseeable misuse..... | 17 |
| 8.3.1 | External short circuit (cell)..... | 17 |
| 8.3.2 | External short circuit (battery)..... | 17 |
| 8.3.3 | Free fall..... | 18 |
| 8.3.4 | Thermal abuse (cells)..... | 18 |

| | | |
|-------|--|----|
| 8.3.5 | Crush (cells)..... | 18 |
| 8.3.6 | Over-charging of battery..... | 18 |
| 8.3.7 | Forced discharge (cells)..... | 19 |
| 8.3.8 | Transport tests..... | 19 |
| 8.3.9 | Design evaluation - Forced internal short circuit (cells)..... | 19 |
| 9 | Information for safety..... | 21 |
| 10 | Marking..... | 21 |
| 10.1 | Cell marking..... | 21 |
| 10.2 | Battery marking..... | 22 |
| 10.3 | Other information..... | 22 |
| 11 | Packaging..... | 22 |
| | Annex A (normative) Charging range of secondary lithium ion cells for safe use..... | 23 |
| | Annex B (informative) Recommendations to equipment manufacturers and battery assemblers..... | 34 |
| | Annex C (informative) Recommendations to the end-users..... | 35 |
| | Bibliography..... | 36 |
| | Figure 1 - Temperature profile for 7.2.4 - Temperature cycling test..... | 13 |
| | Figure 2 - Jig for pressing..... | 21 |
| | Figure A.1 - Typical of operating region of Li-ion cells with cobalt oxide cathode and carbon anode..... | 24 |
| | Figure A.2 - Shape of nickel particle..... | 28 |
| | Figure A.3 - Nickel particle insertion position between positive and negative active material coated area of cylindrical cell..... | 29 |
| | Figure A.4 - Nickel particle insertion position between positive aluminum foil and negative active material coated area of cylindrical cell..... | 29 |
| | Figure A.5 - Disassembly of cylindrical cell..... | 30 |
| | Figure A.6 - Nickel particle insertion position between positive and negative (active material) coated area of prismatic cell..... | 31 |
| | Figure A.7 - Nickel particle insertion position between positive aluminum foil and negative (active material) coated area of prismatic cell..... | 32 |
| | Figure A.8 - Disassembly of prismatic cells..... | 33 |
| | Table 1 - Sample size for type tests (nickel systems)..... | 11 |
| | Table 2 - Sample size for type tests (lithium systems)..... | 11 |
| | Table 3 - Conditions for vibration test..... | 12 |
| | Table 4 - Condition of charging procedure..... | 16 |
| | Table 5 - Ambient temperature for cell test ^a | 20 |

**SECONDARY CELLS AND BATTERIES CONTAINING ALKALINE
OR OTHER NON-ACID ELECTROLYTES -**

**SAFETY REQUIREMENTS FOR PORTABLE SEALED
SECONDARY CELLS, AND FOR BATTERIES MADE FROM THEM,
FOR USE IN PORTABLE APPLICATIONS**

1 Scope

This International Standard specifies requirements and tests for the safe operation of portable sealed secondary cells and batteries (other than button) containing alkaline or other non-acid electrolyte, under intended use and reasonably foreseeable misuse.

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.

IEC 60050-482, *International Electrotechnical Vocabulary - Part 482: Primary and secondary cells and batteries*

IEC 61951-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 1: Nickel-cadmium*

IEC 61951-2, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 2: Nickel-metal hydride*

IEC 61960, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications*

ISO/IEC Guide 51, *Safety aspects - Guidelines for their inclusion in standards*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-482 and ISO/IEC Guide 51, as well as the following apply.

3.1

safety

freedom from unacceptable risk

3.2

risk

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

3.3

harm

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

3.4

hazard

potential source of harm

3.5

intended use

use of a product, process or service in accordance with specifications, instructions and information provided by the supplier

3.6

reasonably foreseeable misuse

use of a product, process or service in a way which is not intended by the supplier, but which may result from readily predictable human behaviour

3.7

secondary cell

basic manufactured unit providing a source of electrical energy by direct conversion of chemical energy, that consists of electrodes, separators, electrolyte, container and terminals, and that is designed to be charged electrically

3.8

secondary battery

assembly of secondary cell(s) ready for use as a source of electrical energy characterized by its voltage, size, terminal arrangement, capacity and rate capability

3.9

leakage

visible escape of liquid electrolyte

3.10

venting

release of excessive internal pressure from a cell/battery in a manner intended by design to preclude rupture or explosion

3.11

rupture

mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage but not ejection of materials

3.12

explosion

failure that occurs when a cell container or battery case opens violently and major components are forcibly expelled

3.13

fire

the emission of flames from a cell or battery

3.14

portable battery

a battery for use in a device or appliance which is conveniently hand carried

3.15

portable cell

a cell intended for assembly in a portable battery

<http://www.china-gauges.com/>

3.16

polymer cell

cell using gel polymer electrolyte or solid polymer electrolyte, not liquid electrolyte

3.17

rated capacity

quantity of electricity c_5 , Ah (ampere-hours) declared by the manufacturer which a single cell can deliver when discharged at the reference test current of $0,2 I_n$ to a specified final voltage, after charging, storing and discharging under specified conditions

3.18

upper limit charging voltage

the highest charging voltage in the cell operating region specified by the cell manufacturer

3.19

maximum charging current

the maximum charging current in the cell operating region which is specified by the cell manufacturer

4 Parameter measurement tolerances

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

- a) $\pm 1 \%$ for voltage;
- b) $\pm 1 \%$ for current;
- c) $\pm 2 \text{ }^\circ\text{C}$ for temperature;
- d) $\pm 0,1 \%$ for time;
- e) $\pm 1 \%$ for dimension;
- f) $\pm 1 \%$ for capacity.

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

For assistance in selecting instrumentation see IEC 60051 series for analogue instruments and IEC 60485 for digital instruments. The details of the instrumentation used shall be provided in any report of results.

5 General safety considerations

5.1 General

The safety of secondary cells and batteries requires the consideration of two sets of applied conditions:

- intended use;
- reasonably foreseeable misuse.

Cells and batteries shall be so designed and constructed that they are safe under conditions of both intended use and reasonably foreseeable misuse. It is expected that cells or batteries subjected to misuse may fail to function following such experience. They shall not however present significant hazards. It may also be expected that cells and batteries subjected to intended use shall not only be safe but shall continue to be functional in all respects.

Potential hazards which are the subject of this standard are:

- a) fire,
- b) burst/explosion,
- c) leakage of cell electrolyte,
- d) venting,
- e) burns from excessively high external temperatures,
- f) rupture of battery case with exposure of internal components.

Conformity with 5.2 to 5.7 is checked by inspection, by the tests of Clauses 7 and 8, and in accordance with the appropriate standard (see Clause 2).

5.2 Insulation and wiring

The insulation resistance between the positive terminal and externally exposed metal surfaces of the battery excluding electrical contact surfaces shall be not less than 5 M Ω at 500 V d. c. when measured 60 s after applying the voltage.

Internal wiring and its insulation shall be sufficient to withstand the maximum anticipated current, voltage and temperature requirements. The orientation of wiring shall be such that adequate clearances and creepage distances are maintained between connectors. The mechanical integrity of internal connections shall be sufficient to accommodate conditions of reasonably foreseeable misuse.

5.3 Venting

Battery cases and cells shall incorporate a pressure relief mechanism or shall be so constructed that they will relieve excessive internal pressure at a value and rate that will preclude rupture, explosion and self-ignition. If encapsulation is used to support cells within an outer case, the type of encapsulant and the method of encapsulation shall neither cause the battery to overheat during normal operation nor inhibit pressure relief.

5.4 Temperature/voltage/current management

The design of batteries shall be such that abnormal temperature-rise conditions are prevented. Batteries shall be designed to be within temperature, voltage and current limits specified by the cell manufacturer. Batteries shall be provided with specifications and charging instructions for equipment manufacturers so that associated chargers are designed to maintain charging within the temperature, voltage and current limits specified.

NOTE Where necessary, means can be provided to limit current to safe levels during charge and discharge.

5.5 Terminal contacts

Terminals shall have clear polarity marking on the external surface of the battery. The size and shape of the terminal contacts shall ensure that they can carry the maximum anticipated current. External terminal contact surfaces shall be formed from conductive materials with good mechanical strength and corrosion resistance. Terminal contacts shall be arranged so as to minimize the risk of short circuits.

NOTE Exception: Battery packs with keyed external connectors designed for connection to specific end products need not be marked with polarity markings if the design of the external connector prevents reverse polarity connections.

5.6 Assembly of cells into batteries

5.6.1 General

If there is more than one battery housed in a single battery case, cells used in the assembly of each battery shall have closely matched capacities, be of the same design, be of the same

chemistry and be from the same manufacturer. Each battery shall have an independent control and protection. Manufacturers of cells shall make recommendations about current, voltage and temperature limits so that the battery manufacturer/designer may ensure proper design and assembly. Batteries that are designed for the selective discharge of a portion of their series connected cells shall incorporate separate circuitry to prevent the cell reversal caused by uneven discharges. Protective circuit components should be added as appropriate and consideration given to the end-device application. When testing a battery, the manufacturer of the battery shall provide a test report confirming the compliance according to this standard. Conformity shall be checked by inspection.

5.6.2 Design recommendation for lithium systems

The voltage of each cell, or each cellblock consisting of parallel-connected plural cells, should not exceed the upper limit of the charging voltage specified in Table 4, excepting the case where the portable electronic devices of the likes have the equivalent function.

The following should be considered at the battery pack level and by the device designer:

- for the battery consisting of a single cell or a single cellblock, it is recommended that the charging voltage of the cell does not exceed the upper limit of the charging voltage specified in Table 4;
- for the battery consisting of series-connected plural single cells or series-connected plural cellblocks, it is recommended that the voltages of any one of the single cells or single cellblocks does not exceed the upper limit of the charging voltage, specified in Table 4, by monitoring the voltage of every single cell or the single cellblocks;
- for the battery consisting of series-connected plural single cells or series-connected plural cellblocks, it is recommended that charging is stopped when the upper limit of the charging voltage is exceeded for any one of the single cells or single cellblocks by measuring the voltage of every single cell or the single cellblocks.

5.7 Quality plan

The manufacturer shall prepare and implement a quality plan that defines procedures for the inspection of materials, components, cells and batteries and which covers the whole process of producing each type of cell or battery. Manufacturers should understand their process capabilities and should institute the necessary process controls as they relate to product safety.

6 Type test conditions

Tests are made with the number of cells or batteries specified in Table 1 for nickel-cadmium and nickel-metal hydride systems and Table 2 for lithium systems, using cells or batteries that are not more than six months old. Unless otherwise specified, tests are carried out in an ambient temperature of $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

NOTE Test conditions are for type tests only and do not imply that intended use includes operation under these conditions. Similarly, the limit of six months is introduced for consistency and does not imply that battery safety is reduced after six months.

Table 1 - Sample size for type tests (nickel systems)

| Test | Cell | Battery |
|------------------------------|----------------------|----------------|
| 7.2.1 Low rate charging | 5 | - |
| 7.2.2 Vibration | 5 | 5 |
| 7.2.3 Moulded case stress | - | 3 |
| 7.2.4 Temperature cycling | 5 | - |
| 7.3.1 Incorrect Installation | 5 sets of 4 | - |
| 7.3.2 External short circuit | 5 /Temperature | 5 /Temperature |
| 7.3.3 Free fall | - | 3 |
| 7.3.4 Mechanical shock | 5 | 5 |
| 7.3.5 Thermal abuse | 5 | - |
| 7.3.6 Crush | 5 (10 for prismatic) | - |
| 7.3.7 Low pressure | 3 | - |
| 7.3.8 Overcharge | 5 | 5 |
| 7.3.9 Forced discharge | 5 | - |

Table 2 - Sample size for type tests (lithium systems)

| Test | Cell | Battery |
|--|------------------|------------------|
| 8.1.2 Charge (Procedure 2) | 5/Temp/Condition | 5/Temp/Condition |
| 8.2.1 Continuous charge | 5 | - |
| 8.2.2 Moulded case stress | - | 3 |
| 8.3.1 External short circuit | 5/Temp | - |
| 8.3.2 External short circuit | - | 5/Temp |
| 8.3.3 Free fall | 3 | 3 |
| 8.3.4 Thermal abuse | 5/Temp | - |
| 8.3.5 Crush | 5/Temp | - |
| 8.3.6 Overcharge | - | 5 |
| 8.3.7 Forced Discharge | 5 | - |
| 8.3.8 Transport | (20) | - |
| 8.3.9 Forced Internal Short ^a | 10 | - |

^a Country specific test: only required for listed countries.

7 Specific requirements and tests (nickel systems)

7.1 Charging procedure for test purposes

Unless otherwise stated in this standard, the charging procedure for test purposes is carried out in an ambient temperature of 20 °C ± 5 °C, using the method declared by the manufacturer.

Prior to charging, the battery shall have been discharged at 20 °C ± 5 °C at a constant current of 0,2 I_t A down to a specified final voltage.

Warning: THESE TESTS USE PROCEDURES WHICH MAY RESULT IN HARM IF ADEQUATE PRECAUTIONS ARE NOT TAKEN. TESTS SHOULD ONLY BE PERFORMED BY QUALIFIED AND EXPERIENCED TECHNICIANS USING ADEQUATE PROTECTION. TO PREVENT BURNS, CAUTION SHOULD BE TAKEN FOR THOSE CELLS OR BATTERIES WHOSE CASINGS MAY EXCEED 75 °C AS A RESULT OF TESTING.

7.2 Intended use

7.2.1 Continuous low-rate charging {cells}

a) Requirement

A continuous low-rate charge shall not cause fire or explosion.

b) Test

Fully charged cells are subjected for 28 days to a charge as specified by the manufacturer.

c) Acceptance criteria

No fire, no explosion.

7.2.2 Vibration

a) Requirements

Vibration encountered during transportation shall not cause leakage, fire or explosion.

b) Test

Fully charged cells or batteries are vibration-tested under the following test conditions and the sequence in Table 3. A simple harmonic motion is applied to the cells or batteries with an amplitude of 0,76 mm, and a total maximum excursion of 1,52 mm. The frequency is varied at the rate of 1 Hz/min between the limits of 10 Hz and 55 Hz. The entire range of frequencies (10 Hz to 55 Hz) and return (55 Hz to 10 Hz) is traversed in 90 min ± 5 min for each mounting position (direction of vibration). The vibration is applied in each of three mutually perpendicular directions, in the sequence specified below.

Step 1: Verify that the measured voltage is typical of the charged product being tested.

Steps 2-4: Apply the vibration as specified in Table 3.

Step 5: Rest cell for 1 h, and then make a visual inspection.

c) Acceptance criteria

No fire, no explosion, no leakage.

Table 3 - Conditions for vibration test

| Step | Rest time h | Vibration time min | Visual examination |
|------|----------------|-----------------------|--------------------|
| 1 | - | - | Pre-test |
| 2 | - | 90 ±5 | - |
| 3 | - | 90 ±5 | - |
| 4 | - | 90 ± 5 | - |
| 5 | 1 | - | Post-test |

7.2.3 Moulded case stress at high ambient temperature (batteries)

a) Requirement

Internal components of batteries shall not be exposed during use at high temperature.

b) Test

Fully charged batteries are exposed to a moderately high temperature to evaluate case integrity. The battery is placed in an air circulating oven at a temperature of $70\text{ °C} \pm 2\text{ °C}$. The batteries remain in the oven for 7 h, after which they are removed and allowed to return to room temperature.

c) Acceptance criteria

No physical distortion of the battery case resulting in exposure of internal components.

7.2.4 Temperature cycling

a) Requirements

Repeated exposure to high and low temperatures shall not cause fire or explosion.

b) Test according to the following procedure and the profile shown in Figure 1.

Fully charged cells or batteries are subjected to temperature cycling (-20 °C , $+75\text{ °C}$), in forced draught chambers according to the following procedure.

Step 1: Place the cells or batteries in an ambient temperature of $75\text{ °C} + 2\text{ °C}$ for 4 h.

Step 2: Change the ambient temperature to $20\text{ °C} + 5\text{ °C}$ within 30 min and maintain at this temperature for a minimum of 2 h.

Step 3: Change the ambient temperature to $-20\text{ °C} \pm 2\text{ °C}$ within 30 min and maintain at this temperature for 4 h.

Step 4: Change the ambient temperature to $20\text{ °C} \pm 5\text{ °C}$ within 30 min and maintain at this temperature for a minimum of 2 h.

Step 5: Repeat steps 1 to 4 for a further four cycles.

Step 6: After the fifth cycle, store the cells or batteries and check after a rest period of at least 24 h.

NOTE This test can be performed in a single chamber whose temperature is changed or in three separate chambers at three different test temperatures.

c) Acceptance criteria

No fire, no explosion, no leakage.

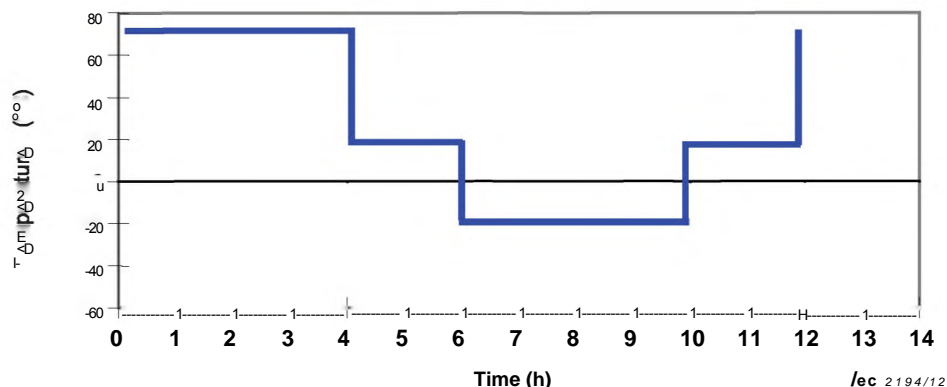


Figure 1 - Temperature profile for 7.2.4 - Temperature cycling test

7.3 Reasonably foreseeable misuse

7.3.1 Incorrect installation (cells)

a) Requirements

The incorrect installation of a single cell in a multi-cell application shall not cause fire or explosion.

b) Test

Fully charged cells are evaluated under conditions in which one of the cells is incorrectly installed. Four fully charged single cells of the same brand, type, size and age are connected in series with one of the four cells reversed. The resultant assembly is connected across a resistor of 1 Ω until the vent opens or until the temperature of the reversed cell returns to ambient temperature. Alternatively, a stabilized d.c. power supply can be used to simulate the conditions imposed on the reversed cell.

- c) Acceptance criteria
No fire, no explosion.

7.3.2 External short circuit

- a) Requirements

Short-circuiting of the positive and negative terminals shall not cause fire or explosion.

- b) Test

Two sets of fully charged cells or batteries are stored in an ambient temperature of $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and $+15\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ respectively. Each cell or battery is then short-circuited by connecting the positive and negative terminals with a total external resistance of $80\text{ m}\Omega \pm 20\text{ m}\Omega$. The cells or batteries remain on test for 24 h or until the case temperature declines by 20 % of the maximum temperature rise, whichever is the sooner.

- c) Acceptance criteria
No fire, no explosion.

7.3.3 Free fall

- a) Requirements

Dropping a cell or battery (for example, from a bench top) shall not cause fire or explosion.

- b) Test

Each fully charged cell or battery is dropped three times from a height of 1,0 m onto a concrete floor. The cells or batteries are dropped so as to obtain impacts in random orientations. After the test, the sample shall be put on rest for a minimum of one hour and then a visual inspection shall be performed.

- c) Acceptance criteria
No fire, no explosion.

7.3.4 Mechanical shock (crash hazard)

- a) Requirements

Shocks encountered during handling or transportation shall not cause fire, explosion or leakage.

- b) Test

The fully charged cell or battery is secured to the testing machine by means of a rigid mount which will support all mounting surfaces of the cell or battery. The cell or battery is subjected to a total of three shocks of equal magnitude. The shocks are applied in each of three mutually perpendicular directions. At least one of them shall be perpendicular to a flat face.

For each shock the cell or battery is accelerated in such a manner that during the initial 3 ms the minimum average acceleration is 75 g_n . The peak acceleration shall be between 125 g_n and 175 g_n . Cells or batteries are tested in an ambient temperature of $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. After the test, the sample shall be put on rest for a minimum of one hour and then a visual inspection shall be performed.

- c) Acceptance criteria
No fire, no explosion, no leakage.

7.3.5 Thermal abuse (cells)

a) Requirements

An extremely high temperature shall not cause fire or explosion.

b) Test

Each fully charged cell, stabilized at room temperature, is placed in a gravity or circulating air-convection oven. The oven temperature is raised at a rate of $5\text{ °C/min} \pm 2\text{ °C/min}$ to a temperature of $130\text{ °C} \pm 2\text{ °C}$. The cell remains at this temperature for 10 min before the test is discontinued.

c) Acceptance criteria

No fire, no explosion.

7.3.6 Crushing of cells

a) Requirements

Severe crushing of a cell (for example, during disposal in a waste compactor) shall not cause fire or explosion.

b) Test

Each fully charged cell is crushed between two flat surfaces. The force for the crushing is applied by a hydraulic ram exerting a force of $13\text{ kN} \pm 1\text{ kN}$. The crushing is performed in a manner that will cause the most adverse result. Once the maximum force has been applied, or an abrupt voltage drop of one-third of the original voltage has been obtained, the force is released.

A cylindrical or prismatic cell is crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. To test both wide and narrow sides of prismatic cells, a second set of cells is tested, rotated 90° around their longitudinal axes compared to the first set.

c) Acceptance criteria

No fire, no explosion.

7.3.7 Low pressure (cells)

a) Requirements

Low pressure (for example, during transportation in an aircraft cargo hold) shall not cause fire or explosion.

b) Test

Each fully charged cell is placed in a vacuum chamber, in an ambient temperature of $20\text{ °C} \pm 5\text{ °C}$. Once the chamber has been sealed, its internal pressure is gradually reduced to a pressure equal to or less than 11,6 kPa (this simulates an altitude of 15 240 m) held at that value for 6 h.

c) Acceptance criteria

No fire, no explosion, no leakage.

7.3.8 Overcharge

a) Requirements

Charging for longer periods and at a higher rate than specified by the manufacturer shall not cause fire or explosion.

b) Test

A discharged cell or battery is subjected to a high-rate charge of 2,5 times the recommended charging current for a time that produces a 250 % charge input (250 % of rated capacity).

c) Acceptance criteria

No fire, no explosion.

7.3.9 Forced discharge (cells)

a) Requirements

A cell in a multi-cell application shall withstand polarity reversal without causing fire or explosion.

b) Test

A discharged cell is subjected to a reverse charge at $1/4 I_t$ A for 90 min.

c) Acceptance criteria

No fire, no explosion.

8 Specific requirements and tests (lithium systems)

8.1 Charging procedures for test purposes

8.1.1 First procedure

(This charging procedure applies to subclauses other than those specified in 8.1.2)

Unless otherwise stated in this standard, the charging procedure for test purposes is carried out in an ambient temperature of $20\text{ °C} \pm 5\text{ °C}$, using the method declared by the manufacturer.

Prior to charging, the battery shall have been discharged at $20\text{ °C} \pm 5\text{ °C}$ at a constant current of $0,27 I_t$ A down to a specified final voltage.

8.1.2 Second procedure

(This charging procedure applies only to 8.3.1, 8.3.2, 8.3.4, 8.3.5, and 8.3.9)

After stabilization for 1 to 4 hours respectively at ambient temperature of highest test temperature and lowest test temperature, as specified in Table 4 (currently for lithium cobalt oxide), cells are charged by using the upper limited charging voltage and maximum charging current, until the charging current is reduced to $0,057 I_t$ A, using a constant voltage charging method.

Table 4 - Condition of charging procedure

| Upper limit charging voltage | Maximum charging current | Charging temp. Upper limit | Charging temp. Lower limit |
|------------------------------|--|----------------------------|----------------------------|
| 4,25 V/cell | Specified by the manufacturer of cells | 45 °C | 10 °C |

If a cell's specified upper and/or lower charging temperature exceeds values for the upper and/or lower limit test temperatures of Table 4, the cell shall be charged, and if applicable tested, at the specified values plus 5 °C for the upper limit and minus 5 °C for the lower limit. The cells shall fulfil the criteria of 8.3.1, 8.3.2, 8.3.4, 8.3.5, and 8.3.9. There shall also be a valid rationale provided regarding how the cell's safety is ensured. (See Figure A.1)

NOTE 1 In case of a different upper limit charging voltage (i.e. other than for lithium cobalt oxide systems at 4,25 V), it can be appropriate to adjust the upper limit charging voltage and upper limit charging temperatures accordingly to fulfil the criteria of 8.3.1, 8.3.2, 8.3.4, 8.3.5, and 8.3.9 and have a valid rationale to ensure the safety of the cell. (See Figure A.1)

NOTE 2 New chemistries systems will be incorporated in the standard when new data becomes available.

| |
|--|
| Warning: THESE TESTS USE PROCEDURES WHICH MAY RESULT IN HARM IF ADEQUATE PRECAUTIONS ARE NOT TAKEN. TESTS SHOULD ONLY BE PERFORMED BY QUALIFIED AND EXPERIENCED TECHNICIANS USING ADEQUATE PROTECTION. TO PREVENT BURNS, CAUTION SHOULD BE TAKEN FOR THOSE CELLS OR BATTERIES WHOSE CASINGS MAY EXCEED 75 °C AS A RESULT OF TESTING |
|--|

8.2 Intended use

8.2.1 Continuous charging at constant voltage (cells)

a) Requirement

A continuous charge at constant voltage shall not cause fire or explosion.

b) Test

Fully charged cells are subjected for 7 days to a charge as specified by the manufacturer.

c) Acceptance criteria

No fire, no explosion, no leakage

8.2.2 Moulded case stress at high ambient temperature (battery)

a) Requirement

Internal components of batteries shall not be exposed during use at high temperature.

b) Test

Fully charged batteries, according to the first procedure in 8.1.1, are exposed to a moderately high temperature to evaluate case integrity. The battery is placed in an air circulating oven at a temperature of $70\text{ °C} \pm 2\text{ °C}$. The batteries remain in the oven for 7 h, after which they are removed and allowed to return to room temperature.

c) Acceptance criteria

No physical distortion of the battery case resulting in exposure of internal components.

8.3 Reasonably foreseeable misuse

8.3.1 External short circuit (cell)

a) Requirements

Short-circuiting of the positive and negative terminals of the cell at ambient temperature shall not cause fire or explosion.

b) Test

Fully charge each cell according to the second procedure in 8.1.2. The cell is short-circuited by connecting the positive and negative terminals with a total external resistance of $80\text{ m}\Omega \pm 20\text{ m}\Omega$. The cell remains on test for 24 h or until the surface temperature declines by 20 % of the maximum temperature rise, whichever is the sooner.

c) Acceptance criteria

No fire, no explosion.

8.3.2 External short circuit (battery)

a) Requirements

Short-circuiting of the positive and negative terminals of the battery pack shall not cause fire or explosion.

b) Test

Each fully charged battery according to the second procedure in 8.1.2 is stored in an ambient temperature $55\text{ °C} \pm 5\text{ °C}$. The battery pack is then short-circuited by connecting the positive and negative terminals with a total external resistance of $80\text{ m}\Omega \pm 20\text{ m}\Omega$. The battery pack remains on test for 24 h or until the case temperature of battery pack declines by 20 % of the maximum temperature rise, whichever is the sooner. However, in

case of rapid decline in short circuit current, the battery pack should remain on test for an additional one hour after the current reaches a low end steady state condition. This typically refers to a condition where the per cell voltage (series cells only) of the battery is below 0,8 V and is decreasing by less than 0,1 V in a 30-minute period.

- c) Acceptance criteria
No fire, no explosion.

8.3.3 Free fall

- a) Requirements

Dropping a cell or battery (for example, from bench top) shall not cause fire or explosion.

- b) Test

Free fall test is conducted at an ambient temperature of $20\text{ °C} \pm 5\text{ °C}$, by using batteries that are charged to a fully charged state, in accordance with the first procedure in 8.1.1. Each fully charged cell or battery is dropped three times from a height of 1,0 m onto a concrete floor. The cells or batteries are dropped so as to obtain impacts in random orientations. After the test, the cell or battery shall be put on rest for a minimum of one hour and then a visual inspection shall be performed.

- c) Acceptance criteria
No fire, no explosion.

8.3.4 Thermal abuse (cells)

- a) Requirements

An extremely high temperature shall not cause fire or explosion.

- b) Test

Each fully charged cell, according to the second procedure in 8.1.2, is placed in a gravity or circulating air-convection oven. The oven temperature is raised at a rate of $5\text{ °C/min} \pm 2\text{ °C/min}$ to a temperature of $130\text{ °C} \pm 2\text{ °C}$. The cell remains at this temperature for 10 min (30 min for larger cells) before the test is terminated.

- c) Acceptance criteria
No fire, no explosion.

8.3.5 Crush (cells)

- a) Requirements

Severe crushing of a cell shall not cause fire or explosion.

- b) Test

Each fully charged cell, charged according to the second procedure at the upper limit charging temperature in 8.1.2, is immediately transferred and crushed between two flat surfaces in an ambient temperature. The force for the crushing is applied by a hydraulic ram exerting a force of $13\text{ kN} \pm 1\text{ kN}$. The crushing is performed in a manner that will cause the most adverse result. Once the maximum force has been applied, or an abrupt voltage drop of one-third of the original voltage has been obtained, or 10 % of deformation has occurred compared to the initial dimension, the force is released (whichever condition occurs first should be the indication that the force should be released).

A cylindrical or prismatic cell is crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. Test only the wide side of prismatic cells.

- c) Acceptance criteria
No fire, no explosion.

8.3.6 Over-charging of battery

- a) Requirements

Charging for longer periods than specified by the manufacturer shall not cause fire or explosion

b) Test

The test shall be carried out in an ambient temperature of $+20\text{ °C} \pm 5\text{ °C}$. Each test battery shall be discharged at a constant current of $0,2 I_t$ A, to a final discharge voltage specified by the manufacturer. Sample batteries shall then be charged at a constant current of $2,0 I_t$ A, using a supply voltage (not to exceed the maximum voltage supplied by the recommended charger - if value not available it shall be $5,0 V$ per cell) sufficient to maintain this current of $2,0 I_t$ A throughout the duration of the test or until the supply voltage is reached. A thermocouple shall be attached to each test battery. For battery packs, the temperature shall be measured on the battery pack casing. The test shall be continued until the temperature of the outer casing reaches steady state conditions (less than 10 °C change in 30-minute period) or returns to ambient.

c) Acceptance criteria

No fire, no explosion.

8.3.7 Forced discharge (cells)

a) Requirements

A cell in a multi-cell application shall withstand polarity reversal without causing fire or explosion.

b) Test

A discharged cell is subjected to a reverse charge at $1 I_t$ A for 90 min.

c) Acceptance criteria

No fire, no explosion.

8.3.8 Transport tests

Regulations concerning international transport of lithium ion batteries are based on the UN Recommendations on the Transport of Dangerous Goods. Testing requirements are defined in the UN Manual of Tests & Criteria. As regulations are subject to change, the latest editions should be consulted. For reference, transportation tests are also given in IEC 62281. Manufacturer's documentation can be provided to demonstrate compliance.

8.3.9 Design evaluation - Forced internal short circuit (cells)

a) Requirements

Forced internal short circuit test for cylindrical cells and prismatic cells shall not cause fire. Cell manufacturers shall keep a record to meet the requirements. A new design evaluation shall be done by the cell manufacturer after testing is conducted by the cell manufacturer or a third party test house.

This country specific test which is only applicable to France, Japan, Korea and Switzerland and is not required on polymer cells.

b) Test

The forced internal short circuit test is performed in a chamber at $+10\text{ °C}$ and $+45\text{ °C}$ (ambient internal chamber temperature) according to the following procedure.

1) Number of samples

This test shall be carried out on five secondary (rechargeable) lithium-ion cells.

2) Charging procedure

i) Conditioning charge and discharge

The sample shall be charged at $20\text{ °C} \pm 5\text{ °C}$ according to the manufacturer's recommendation. The sample is then discharged at $20\text{ °C} \pm 5\text{ °C}$ at a constant current of $0,2 I_t$ A down to the final voltage specified by the manufacturer.

ii) Storage procedure

Test cell shall be stored for 1 h to 4 h at an ambient temperature as specified in Table 5.

iii) Ambient temperature

Table 5 - Ambient temperature for cell test ^a

| Test item | Test at lowest test temperature | Test at highest test temperature |
|-----------|---------------------------------|----------------------------------|
| b.2.ii | 10 ± 2 °C | 45 ± 2 °C |
| b.2.iv | 10 + 2 °C | 45 ± 2 °C |
| b.3.iA | 5 + 2 °C | 50 ± 2 °C |
| b.3.iiA | 10 ± 5 °C | 45 ± 5 °C |

^a The test is conducted using conditions in Table 4.

iv) Charging procedure for forced internal short test

Test cell shall be charged at an ambient temperature as specified In Table 5, at the upper limited charging voltage at the constant current specified by the manufacturer, continue charging at constant voltage at upper limited charge current drops to 0,05 I_c A.

3) Pressing the winding core with nickel particle

Temperature-controlled oven and special press equipment are needed for the test.

Moving part of the press equipment shall move at constant speed and can be stopped immediately when short-circuit is detected.

i) Preparation for the test

A The temperature of the oven is controlled as specified in Table 5. Samples preparation guidance is provided in Annex A, Clause A.5 and in Figure A.5 and Figure A.8. Put aluminum-laminated bag with winding core and nickel particle into the oven for 45 ± 15 min.

B Remove the winding core from sealed package and attach terminals for voltage measurement and thermo couple for temperature on the surface of the winding core. Set the winding core under the pressure equipment to locating the point of the place of the nickel particle under the pressing jig.

Remark: To prevent evaporation of electrolyte, finish the work within 10 min from removing the winding core from the oven for temperature conditioning to closing the oven door where the equipment is located.

C Remove insulating sheet and close the oven door.

ii) Internal short circuit

A Confirm that the winding core surface temperature is as defined in Table 5 and then starts the test.

B Bottom surface of moving part of the press equipment is made of Nitrile rubber or Acryl, which is put on the 10 mm x 10 mm stainless steel shaft. The detail of pressing jigs shall be shown in Figure 2. Nitrile rubber bottom surface is for cylindrical cell test. For prismatic test 5 mm x 5 mm (2 mm thickness) Acryl is put on the Nitrile rubber. The fixture is moved down at the speed of 0,1 mm/s monitoring the cell voltage. When voltage drop caused by the internal short-circuit is detected, stop descent immediately and keep pressing jig in the position for 30 s and then release the pressure. Voltage is monitored more than 100 times per second and if voltage is dropped more than 50 mV compare to the initial voltage, it is defined to internal short circuit has occurred. If the pressure reaches 800 N for cylindrical cell and 400 N for prismatic cell, stop descent immediately and then keep in the position.

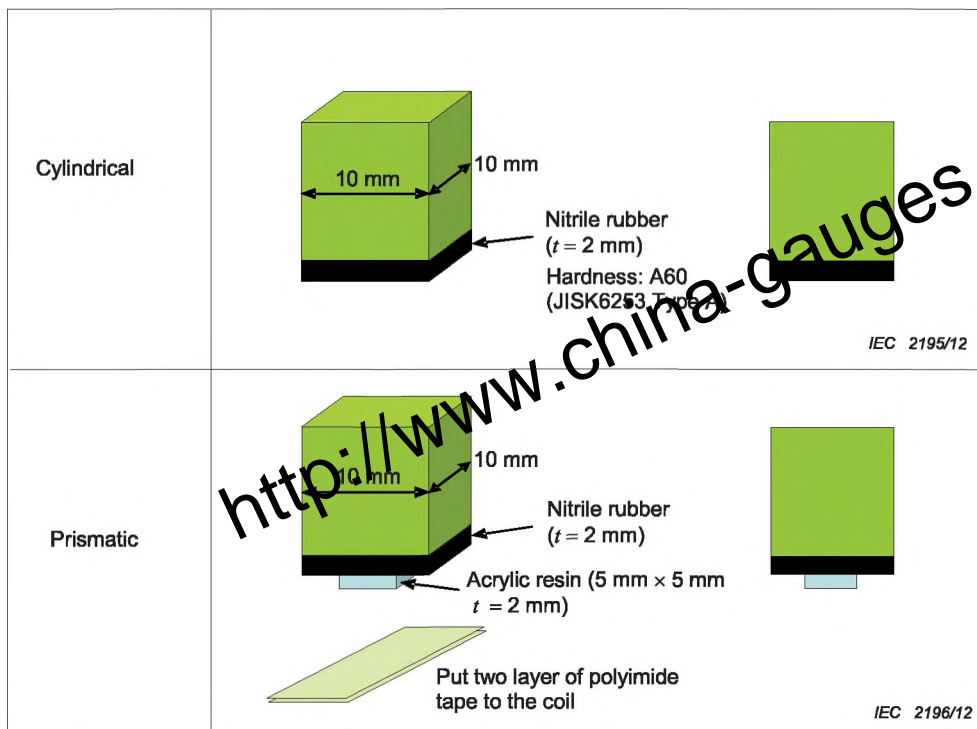


Figure 2 – Jig for pressing

c) Acceptance criteria

No fire. (Record the pressure when short-circuit occurred if there was no fire.)

9 Information for safety

The use, and particularly abuse, of portable sealed secondary cells and batteries containing alkaline or other non-acid electrolyte may result in the creation of hazards and may cause harm. Manufacturers of secondary cells shall ensure that information is provided about current, voltage and temperature limits of their products. Manufacturers of batteries shall ensure that equipment manufacturers and, in the case of direct sales, end-users are provided with information to minimize and mitigate hazards.

It is the equipment manufacturer's responsibility to inform end-users of the potential hazards arising from the use of equipment containing secondary cells and batteries. Systems analyses should be performed by device manufacturers to ensure that a particular battery design prevents hazards from occurring during use of a product. As appropriate, any information relating to hazard avoidance resulting from a system analysis should be provided to the end user.

Guidance is provided in IEC/TR 62188 on the design and manufacture of portable batteries, and non-exhaustive lists of good advices are provided for information in Annexes B and C.

Conformity can be checked by examination of manufacturer's documentation.

10 Marking

10.1 Cell marking

Cells shall be marked as specified in the following applicable cell standards:

IEC 61951-1, IEC 61951-2 or IEC 61960.

NOTE By agreement between the manufacturer and user, cells used in the manufacture of a battery need not be marked.

Conformity is checked by inspection.

10.2 Battery marking

Batteries shall be marked in accordance with the requirements for the cells from which they are assembled. Cell requirements are specified in 10.1. Batteries shall also be marked with an appropriate caution statement.

Conformity is checked by inspection.

10.3 Other information

The following information shall be marked on or supplied with the battery:

- storage and disposal instructions;
- recommended charging instructions.

Conformity is checked by examination of markings and manufacturer's documentation.

11 Packaging

The goal of packaging of secondary cells and batteries for transport is to prevent opportunities for short circuit, mechanical damage and possible ingress of moisture. The materials and pack design shall be chosen so as to prevent the development of unintentional electrical conduction, corrosion of the terminals and ingress of environmental contaminants.

Lithium ion cells and batteries are regulated by ICAO, IATA, IMO and other government agencies. See IEC 62281 for additional information. Nickel metal hydride cells and batteries are regulated by IMO.

Nickel cadmium cells and batteries are not classified as dangerous goods however there are regulations that shall be complied with such as protection from short circuit during transport. Nickel metal hydride cells and batteries are classified as dangerous goods only for maritime transportation.

Annex A
(normative)

Charging range of secondary lithium ion cells for safe use

A.1 General

This annex supplements the descriptions in both the main part and annexes. It constitutes a part of the present standard.

A.2 Safety of lithium-ion secondary battery

In order to ensure the safe use of lithium-ion secondary batteries, manufacturers who design and produce lithium-ion secondary cells or batteries shall strictly observe the requirements which are specified in the present standard. In case of a different upper limit charging voltage (i.e. other than for lithium cobalt oxide systems at 4,25 V), it may be appropriate to adjust the upper limit charging voltage and upper limit charging temperatures accordingly to fulfil the criteria of the tests.

A.3 Consideration on charging voltage

A.3.1 General

The charging voltage shall be applied for secondary cells so as to promote the chemical reaction during charging. However, if the charging voltage is too high, excessive chemical reaction or side reactions occur, and the battery becomes thermally unstable. (It may overheat and thermal runaway may occur.) Consequently, it is most important that the charging voltage never exceeds the value which is specified by the battery manufacturer. On the other hand, battery manufacturers shall verify the safety of secondary cells, which are charged at the specified charging voltage.

A.3.2 Upper limit charging voltage

A.3.2.1 General

Lithium-ion secondary batteries which employ lithium cobalt oxide as the positive active material and carbon as the negative material are the most widely used. In this battery, the upper limited charging voltage, as per defined in 8.1.2 is specified based on the value of 4,25 V for the lithium-ion cell which is a permissible upper limited charging voltage from a safety viewpoint. Figure A.1 illustrates the basic operating region that is recommended for typical lithium-ion batteries which employ lithium cobalt oxide as a positive active material, and carbon as the negative material.

A.3.2.2 Explanation of safety viewpoint

When a lithium-ion battery is charged at a higher voltage than the upper limit of charging voltage, excess amount of lithium-ion is deintercalated from the positive electrode active material and its crystalline structure tends to collapse. As a result, it becomes easy to generate oxygen and metallic lithium may deposit on the carbon surface, which is employed as the negative material.

In these conditions, when an internal short-circuit occurs, thermal runaway can more easily occur than when said battery is charged under the specified condition.

Consequently, lithium-ion secondary battery should never be charged at a higher voltage than this recommended upper limit charging voltage. A suitable protection device shall also be provided, by assuming the possible failure of charge control by charger.

For alternative current of over 50 kHz, which assumes ripple, the above statements are not applicable, since lithium-ion in the battery does not respond to it.

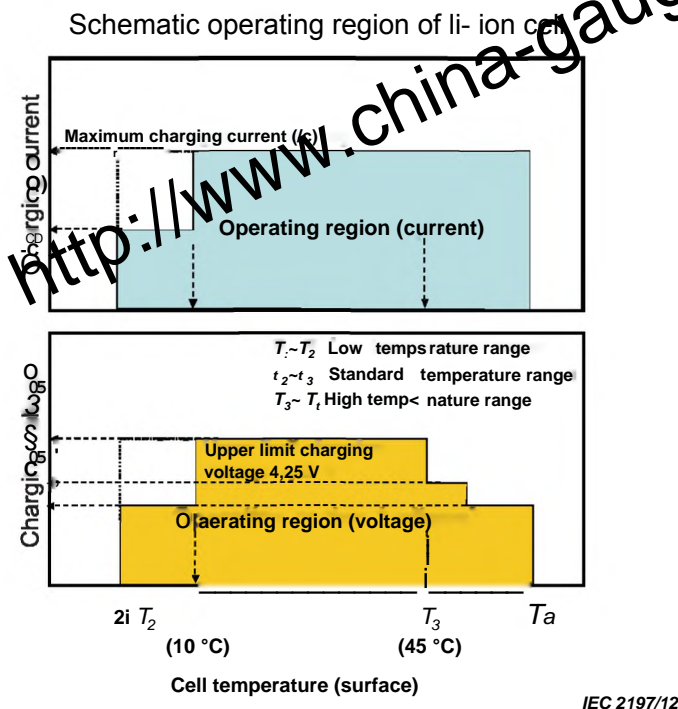


Figure A.1 - Typical of operating region of Li-ion cells with cobalt oxide cathode and carbon anode

A.3.2.3 Safety requirements, when different upper limit charging voltage is applied

It is sometimes necessary that different upper charging voltages, other than 4,25 V be applied for a lithium-ion cell. Examples are as follows:

- positive active material, other than lithium-cobalt-oxide is employed;
- ratio of the capacity of the positive electrode and the negative electrode is changed from the design viewpoint.

When a different upper limit of charging voltage, other than 4,25 V is to be applied for lithium-ion secondary cells, tests that are specified in 8.2 to 8.3 shall be conducted by using cells which are charged under the different upper limited charging voltage. Also, relevant documents, explaining reasons for the change of upper limited charging voltage shall be kept so that said different voltage can be used as the new upper limited charging voltage.

Examples of the documents, explaining reasons of the change of upper limited charging voltage are as follows:

- a) Test results which verify that the stability of crystalline structure of lithium cobalt oxide when the cell is charged at a voltage higher than 4,25 V is equivalent or higher than that when the cell is charged at 4,25 V.
- b) Test results which verify that the acceptance of lithium into the negative active electrode material when the cell is charged at a voltage higher than 4,25 V is equivalent or higher than that when the cell is charged at 4,25 V.

- c) Test results, which verify that the cells, charged at new upper limited charging voltage (higher than 4,25 V) are tested by the test methods at the upper limit of high temperature range and necessary requirements are met.
- d) Test results which verify that the cells charged at a voltage lower than 4,25 V are tested by the test methods at the upper limit of high temperature range and necessary requirements are met.

A.4 Consideration of temperature and charging current

A.4.1 General

Charging produces a chemical reaction and is affected by temperature. The amount of side reaction or the condition of charge products is dependent on temperature even when the same upper limited charging voltage and charging current are employed.

Consequently, it is necessary that one or both of the upper limited charging voltage and maximum charging current shall be reduced at both the low temperature range and high temperature range. These conditions are considered to be more severe than the standard temperature range from a safety viewpoint.

Figure A.1 shows basic operating region under which typical lithium-ion batteries which employ lithium cobalt oxide as the positive active material and carbon as the negative material can be safely charged.

A.4.2 Recommended temperature range

A.4.2.1 General

Within the standard temperature range secondary cells can be charged at both the upper limit of charging voltage and the maximum charging current which is specified from a safety viewpoint.

The upper limit of the test temperature and the lower limit of the test temperature are specified as the highest limit and the lowest limit of standard temperature, respectively. The recommended temperature range of typical lithium-ion batteries which employ lithium-cobalt-oxide as the positive active material and carbon as the negative material is specified as 10 °C to 45 °C.

A.4.2.2 Safety consideration when a different recommended temperature range is applied

In some secondary cells, a different recommended temperature range other than 10 °C to 45 °C is applied due to the difference of thermal stability of the electrolyte and other factors. When a new recommended temperature range is applied, tests that are specified in 8.2 to 8.3 shall be conducted by using cells which are charged at the different test temperature. Also, relevant documents explaining reasons of the change of test temperature shall be kept so that different temperature can be used.

Examples of the documents, explaining reasons of the change of test temperature are as follows:

- a) Test results which verify that the stability of the crystal structure of lithium cobalt oxide, when the cell is charged at the new upper limit of test temperature, higher than 45 °C (highest limit of the standard temperature range) is equivalent or higher than that when the cell is charged at 45 °C.
- b) Test results which verify that the cells, charged at the new upper limit of test temperature (higher than 45 °C + 5 °C), and by using the upper limit of charging voltage are tested by the test methods, specified in 8.2 to 8.3.

- c) Test results which verify that the acceptance of lithium into the negative active material, when the cell is charged at the new lower limit of test temperature, lower than 10 °C, is equivalent or higher than that when the cell is charged at 10 °C.
- d) Test results which verify that the cells, charged at the new lower limit of test temperature (lower than 10 °C -5 °C), and by using the upper limit of charging voltage are tested by the test methods, specified in 8.2 to 8.3.

A.4.3 High temperature range

A.4.3.1 General

In the high temperature range the temperature is higher than in the standard temperature range. Within the high temperature range, charging is permissible by charging at a lower voltage than the upper limited charging voltage which is specified for the standard temperature range.

A.4.3.2 Explanation of safety viewpoint

When lithium-ion is charged at a higher temperature at the same condition as that for the standard temperature range, a larger amount of lithium is deintercalated from the positive electrode active material. Since the increase in the amount of lithium deintercalated leads to deterioration of the stability of the crystalline structure, the safety performance of the battery tends to decrease.

Also the temperature difference between the high temperature range and that at which thermal runaway occurs is relatively small. Consequently, in case there is an accident such as an internal short circuit it is easier for the battery to reach said temperature.

As a result, charging conditions are differently specified in high temperature range, as follows.

- When the surface temperature of the lithium-ion cell is higher than the upper limit of the test temperature a different charging condition which is specially specified for high temperature range is applied.
- When the surface temperature of the lithium-ion cell is higher than the upper limit of the high temperature range said battery shall never be charged under any charging current.

A.4.3.3 Safety considerations when specifying charging conditions in high temperature range

Charging conditions in the high temperature range are sometimes specified based on the thermal stability of the electrolyte and other factors. When charging conditions in the high temperature range are to be specified, test cells shall be charged under these conditions and tested by the test methods specified in 8.2 to 8.3.

A.4.3.4 Safety consideration when specifying new upper limit in high temperature range

In some cases, a different upper limit in high temperature range, other than that shown in Figure A.1 is applied due to the difference of thermal stability of positive electrode active material and other factors. When a new upper limit in the high temperature range is to be adopted, tests that are specified in 8.2 to 8.3 shall be conducted. Also, relevant documents, explaining reasons of the change of high temperature range shall be kept so that the different high temperature range can be used.

Examples of the documents, explaining reasons of the change of high temperature range are as follows:

- a) Test results, which verify that the stability of the crystalline structure of lithium-cobalt-oxide, when the cell is charged at the new upper limit of the high temperature range is

equivalent or higher than that when the cell is charged at the highest limit of the present high temperature range.

- b) Test results which verify that the cells charged at the new upper limit of the high temperature range +5 °C when tested by the methods specified in 8.2 to 8.3 meet the requirements.

A.4.4 Low temperature range

A.4.4.1 General

In the low temperature range, the temperature is lower than that in the standard temperature range. In the low temperature range, charging of the battery is permissible by changing one or both of the upper limits of the charging voltage and maximum charging current which are specified for the standard temperature range.

A.4.4.2 Explanation of safety viewpoint

When a lithium-ion battery is charged in the low temperature range, the mass transfer rate decreases and the lithium ion insertion rate into the carbon active material becomes low. Consequently, metallic lithium is easy to deposit on the carbon surface. In this condition, the battery becomes thermally unstable and may overheat and lead to thermal runaway.

Also, in the low temperature range, the acceptance of lithium ion highly depends on the temperature. Consequently, in a lithium-ion battery which consists of multi-cells of a series connection, the acceptance of lithium ion by these cells can be different due to temperature differences. In this case, sufficient safety may not be ensured.

As a result, charging conditions are differently specified in the low temperature range, as follows:

- When the surface temperature of lithium-ion cells is lower than the lower limited test temperature, different charging conditions which are specially specified for the low temperature range are applied.
- When the surface temperature of lithium-ion cells is lower than the lower limited temperature range, the battery shall never be charged under any charging current.

A.4.4.3 Safety considerations, when specifying charging conditions in low temperature range

Charging conditions in the low temperature range are sometimes specified based on design factors, such as the acceptance of lithium into the negative electrode active material. When charging conditions in the low temperature range are to be specified, test cells shall be charged under these conditions and tested by the test methods specified in 8.2 to 8.3 and meet the requirements.

A.4.4.4 Safety considerations when specifying new lower limit in the low temperature range

In some cases, a different lower limit in the low temperature range other than that shown in Figure A.1 is applied. This may be due to the difference of acceptance of lithium into the negative electrode active material and other factors. When a new lower limit in the low temperature range is to be adopted, tests that are specified in 8.2 to 8.3 shall be conducted and the requirements met. Also, relevant documents explaining the reasons of the change of the low temperature range shall be kept.

Examples of the documents, explaining reasons of the change of low temperature range are as follows:

- a) Test results which verify that the acceptance of lithium into the negative electrode active material when the cell is charged at the new low limit is equivalent or higher than that when the cell is charged at the low limit of the current low temperature range.
- b) Test results which verify that the cells charged at the new low limit of the temperature range $-5\text{ }^{\circ}\text{C}$ when tested by the methods specified in 8.2 to 8.3 meet the requirements.

A.4.5 Scope of the application of charging current

The charging current, as per specified in the above, is not applied to alternative current of over 50 kHz, which assumes ripple and others, since lithium-ion batteries do not respond to such effects. (Ripple currents over 50 kHz are ok)

A.5 Sample preparation

A.5.1 General

In order to provide more information regarding the sample preparation for test 8.3.9 the following additional details are provided.

A.5.2 Insertion procedure for nickel particle to generate internal short

The insertion procedure is carried out at $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and under $-25\text{ }^{\circ}\text{C}$ of DEW points.

A.5.3 Disassembly of charged cell

Remove winding core (assembled electrode/separator, roll, and coil) from the charged cell (See Figure A.5 and Figure A.8).

A.5.4 Shape of nickel particle

The shape of nickel particle shall be as shown in Figure A.2.

Dimensions: Height: 0,2 mm; Thickness: 0,1 mm; L shape (Angle: $90 \pm 10^{\circ}$): 1,0 mm for each side with 5 % tolerance. Material: more than 99 % (mass fraction) pure nickel.

Dimensions in millimeters

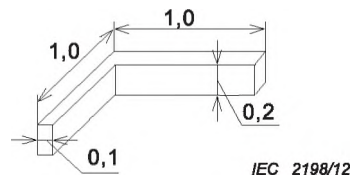


Figure A.2 - Shape of nickel particle

A.5.5 Insertion of nickel particle to cylindrical cell

A.5.5.1 Insertion of nickel particle to winding core

- a) Insertion of nickel particle between positive (active material) coated area and negative (active material) coated area for cylindrical cell, (see Figure A.5)
- 1) If outer turn of positive substrate is aluminum foil, cut off foil at the dividing line between aluminum foil and active material for active material to active material short test.

- 2) Insert nickel particle between positive active material and separator. The alignment of nickel particle shall be as shown in Figure A.3. Position of the insertion of nickel particle shall be at 20 mm from edge of the cut aluminum foil. Direction of L-shaped corner is towards the direction of winding.

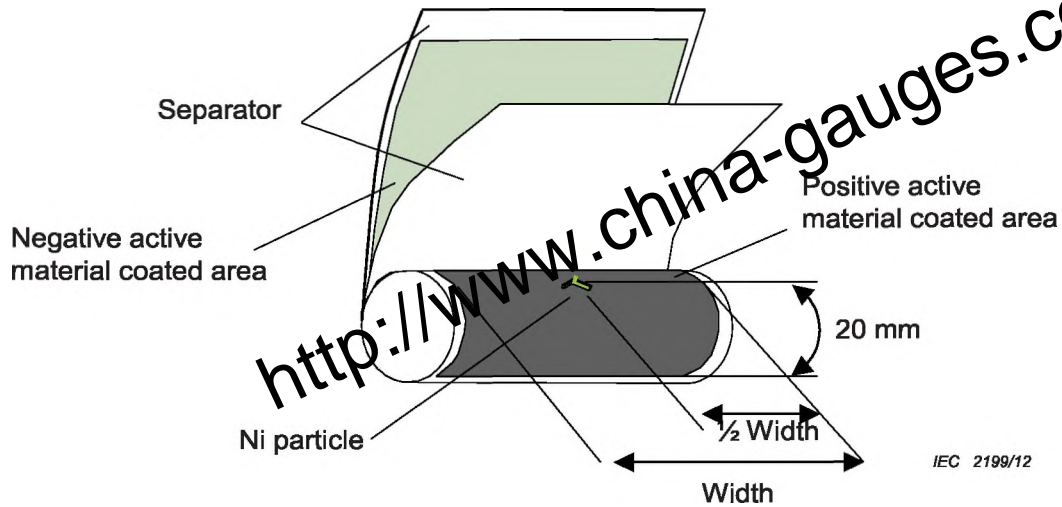


Figure A.3 - Nickel particle insertion position between positive and negative active material coated area of cylindrical cell

- b) Insertion of nickel particle between positive aluminum foil (uncoated area) and negative (active material) coated area for cylindrical cell.

When aluminum foil of positive electrode is exposed at outer turn and the aluminum foil is facing the coated negative active material, following procedure shall be used.

- 1) When aluminum foil of positive electrode is exposed at outer turn, cut out the aluminum foil at 10 mm from the dividing line between aluminum foil and active material.
- 2) Insert Ni particle between aluminum foil and separator. The alignment of nickel particle shall be shown in Figure A.4.

Position of the insertion of nickel particle shall be at 1,0 mm from the edge of the coating of positive active material on aluminum foil.

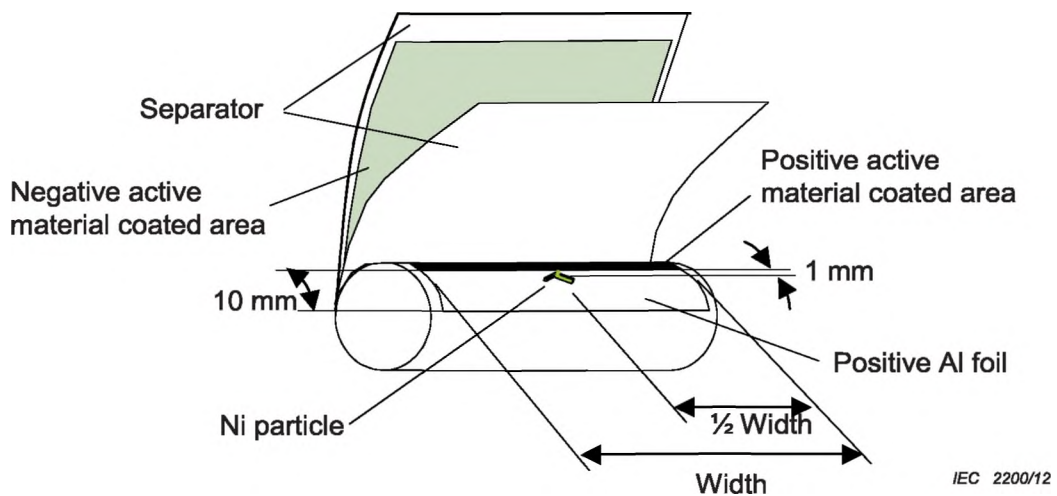
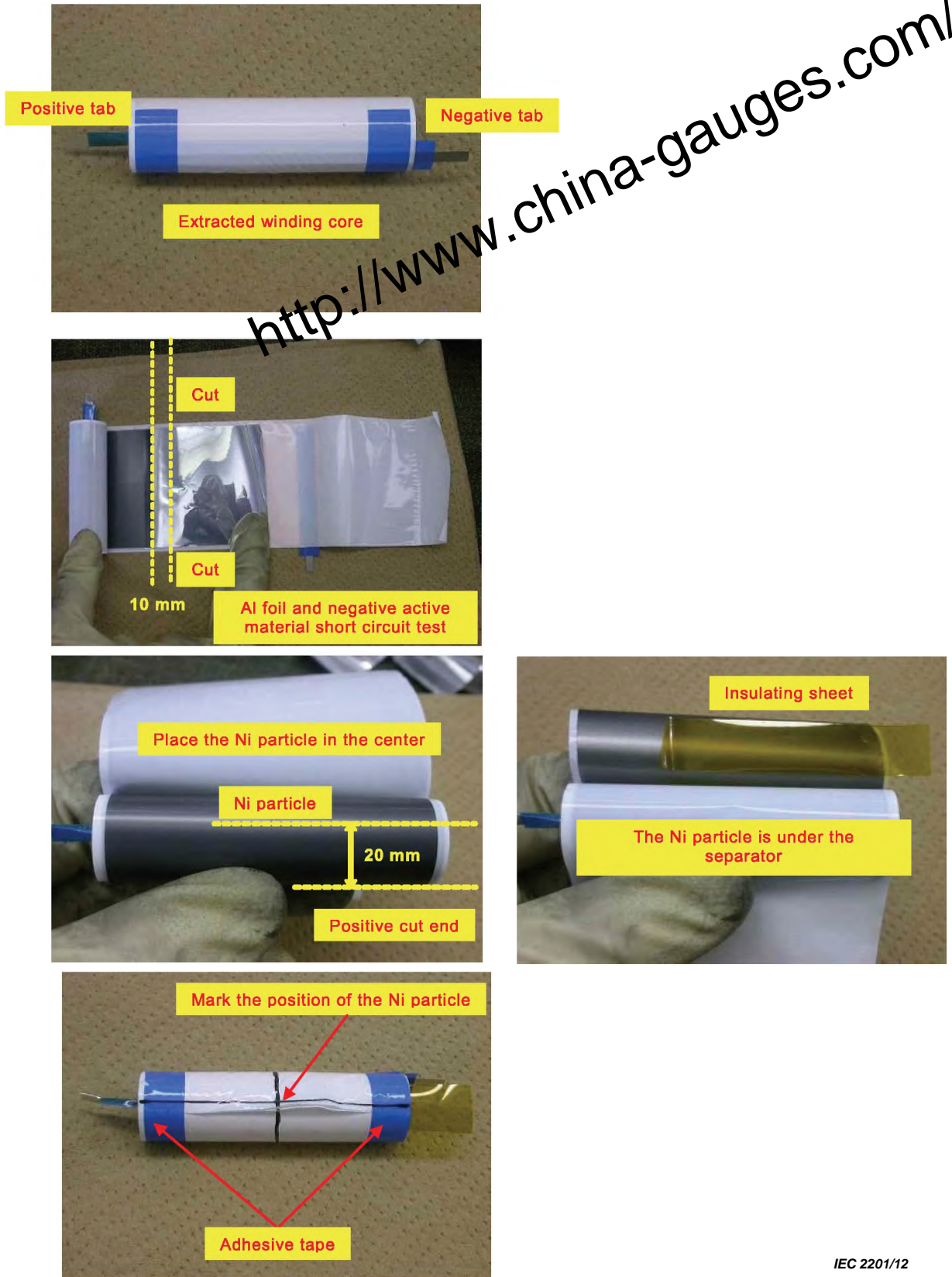


Figure A.4 - Nickel particle insertion position between positive aluminum foil and negative active material coated area of cylindrical cell



IEC 2201/12

Figure A.5 - Disassembly of cylindrical cell

A.5.5.2 Mark the position of nickel particle on the both end of winding core of the separator

The procedure is as follows.

- a) Place insulating sheet between the separator that is facing to nickel particle and the negative electrode to protect against short-circuits.
- b) Manually roll back the electrodes and separator keeping the nickel particle in place and apply adhesive tape to the winding core.
- c) Mark position of the nickel particle across the winding core.
- d) Put winding core in a polyethylene bag with sealing zipper and seal it. Put the polyethylene bag into aluminum-laminated bag to prevent from drying out.

Remark: Procedure shall be completed within 30 min.

A.5.6 Insertion of nickel particle to prismatic cell

- a) Prior to inserting nickel particle, insert an insulating sheet between the negative electrode and the separator that is below nickel particle and the negative electrode, as shown in Figure A.6, to protect against short-circuit.
- b) Insertion of nickel particle to winding core
 - 1) Insertion of nickel particle between positive (active material) coated area and negative (active material) coated area for prismatic cell, (see Figure A.8)
 - i) Insert nickel particle between positive (active material) coated area and separator or between separator and negative (active material) coated area. In case of aluminum cell enclosure, insert nickel particle between positive (active material) coated area and separator.
 - ii) Insert nickel particle between positive active material and separator. The alignment of nickel particle shall be shown in Figure A.6. Nickel particle is set at the center (diagonally) of the winding core. Direction of nickel particle L-shape corner is towards the direction of winding.

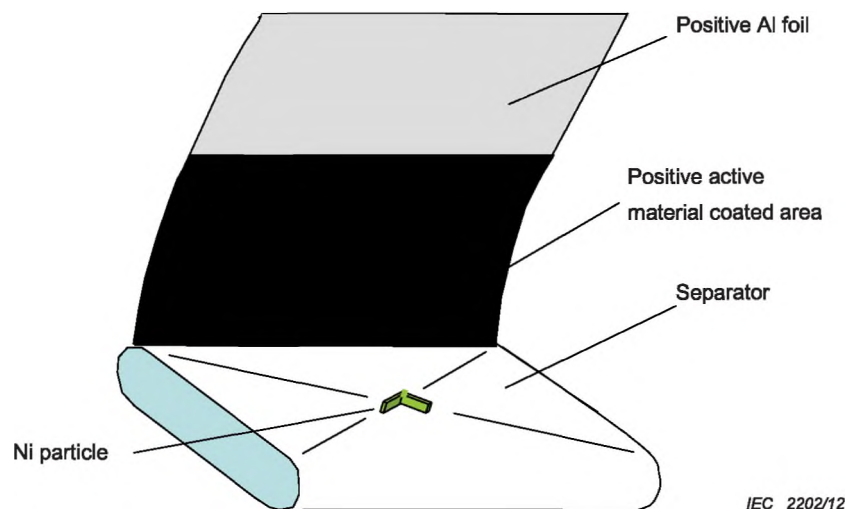


Figure A.6 - Nickel particle insertion position between positive and negative (active material) coated area of prismatic cell

- 2) Insertion of nickel particle between positive aluminum foil (uncoated area) and negative (active material) coated area for prismatic cell. When aluminum foil of positive

electrode is exposed at outer turn and the aluminum foil is faced to coated negative active material, the following test shall be performed:

- i) The aluminum foil of positive electrode is exposed at outer turn and the aluminum foil is faced to coated negative active material, insert nickel particle between aluminum foil and separator;
- ii) The alignment of nickel particle shall be shown in Figure A.7. Nickel particle is set at the centre of flat winding core surface. Direction of nickel particle L - shape corner is towards the direction of winding.

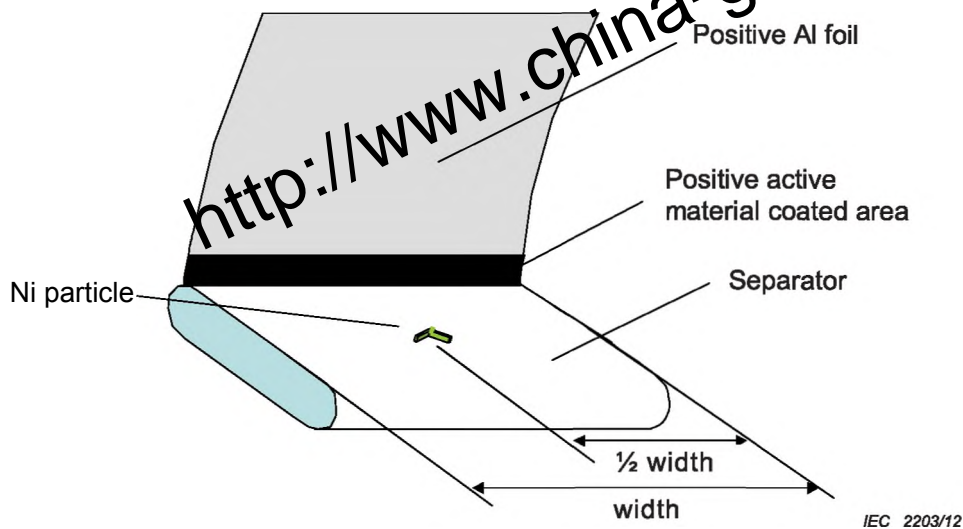
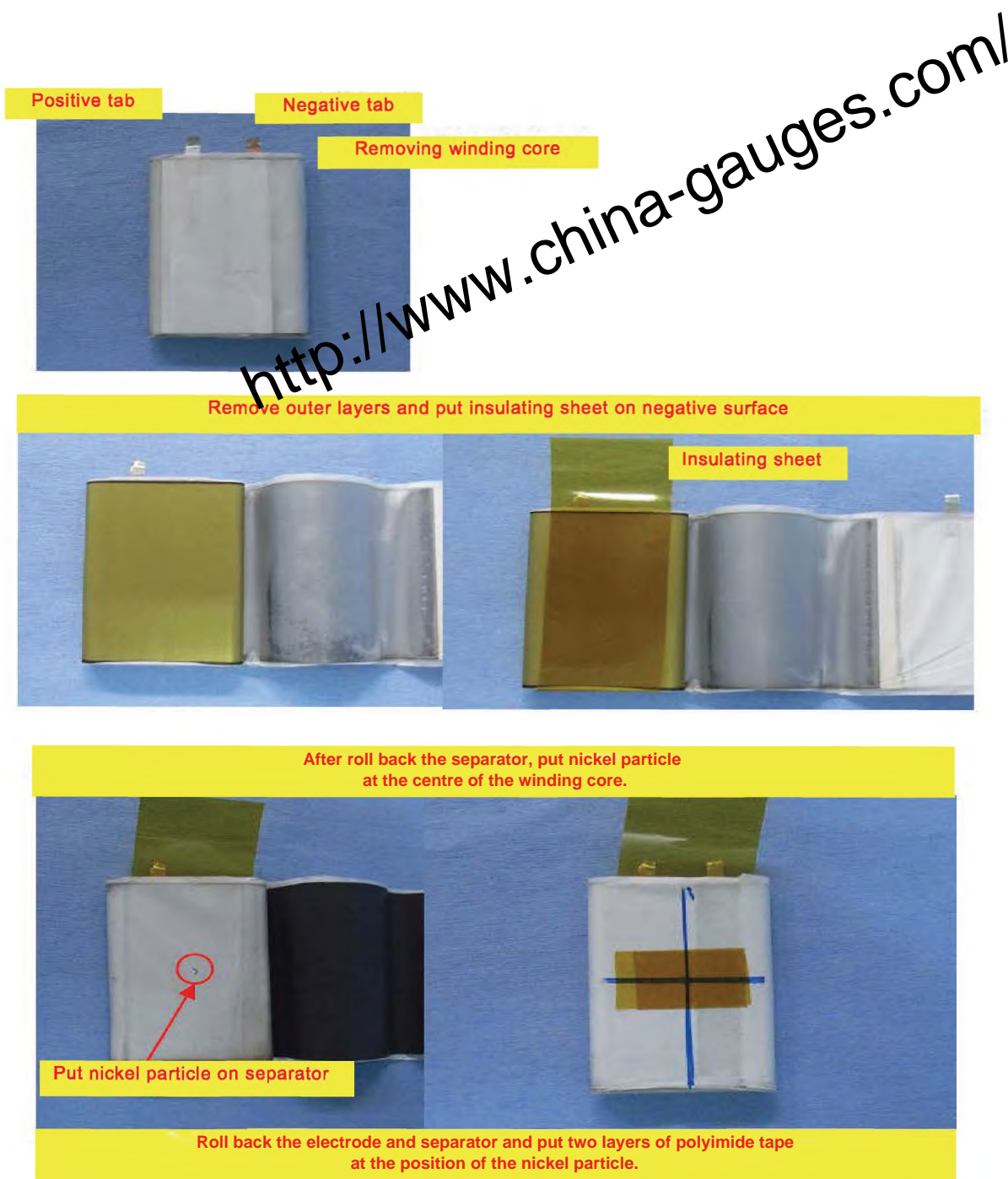


Figure A.7 - Nickel particle insertion position between positive aluminum foil and negative (active material) coated area of prismatic cell

- iii) Manually roll back the electrodes and separator keeping the nickel particle in place and adhesive tape the winding core.
- iv) Mark the position of nickel particle across the winding core.
- v) Put two layers of polyimide tape (10 mm width, 25 µm thickness) at the marking position.
- vi) Put winding core into a polyethylene bag with sealing zipper and seal it. Put the polyethylene bag into aluminum-laminated bag to prevent from drying.

Remark: Procedure should be completed within 30 min.



IEC 2204/12

Figure A.8 - Disassembly of prismatic cells

Annex B
(informative)**Recommendations to equipment manufacturers
and battery assemblers**

The following represents a typical, but non-exhaustive, list of good advice to be provided by the manufacturer of secondary cells and batteries to equipment manufacturers and battery assemblers.

- a) Do not dismantle, open or shred cells. Batteries should be dismantled only by trained personnel. Multi-cell battery cases should be designed so that they can be opened only with the aid of a tool.
- b) Do not short-circuit a cell or battery. Do not store cells or batteries haphazardly in a box or drawer where they may short-circuit each other or be short-circuited by conductive materials.
- c) Do not remove a cell or battery from its original packaging until required for use.
- d) Do not expose cells or batteries to heat or fire. Avoid storage in direct sunlight.
- e) Do not subject cells or batteries to mechanical shock.
- f) In the event of a cell leaking, do not allow the liquid to come into contact with the skin or eyes. If contact has been made, wash the affected area with copious amounts of water and seek medical advice.
- g) Equipment should be designed to prohibit the incorrect insertion of cells or batteries and should have clear polarity marks. Always observe the polarity marks on the cell, battery and equipment and ensure correct use.
- h) Do not mix cells of different manufacture, capacity, size or type within a battery.
- i) Seek medical advice immediately if a cell or battery has been swallowed.
- j) Consult the cell/battery manufacturer on the maximum number of cells, which may be assembled in a battery and on the safest way in which cells may be connected.
- k) A dedicated charger should be provided for each equipment. Complete charging instructions should be provided for all secondary cells and batteries offered for sale.
- l) Keep cells and batteries clean and dry.
- m) Wipe the cell or battery terminals with a clean dry cloth if they become dirty.
- n) Secondary cells and batteries need to be charged before use. Always refer to the cell or battery manufacturer's instructions and use the correct charging procedure.
- o) Do not maintain secondary cells and batteries on charge when not in use.
- p) After extended periods of storage, it may be necessary to charge and discharge the cells or batteries several times to obtain maximum performance.
- q) Retain the original cell and battery literature for future reference.
- r) When disposing of secondary cells or batteries, keep cells or batteries of different electrochemical systems separate from each other.
- s) Drop a device containing the battery once from a height of one meter onto a concrete floor. Test three sets of fully charged batteries. For dropping, select the direction in which the free fall is likely to have the greatest impact on the safety of the battery. Instead of dropping a host device, a shock equivalent to dropping may be given to the battery for simulation.

Annex C
(informative)

Recommendations to the end-users

The following represents a typical, but not exhaustive list of good advice to be provided by the equipment manufacturer to the end-user.

- a) Do not dismantle, open or shred secondary cells or batteries.
- b) Do not expose cells or batteries to heat or fire. Avoid storage in direct sunlight.
- c) Do not short-circuit a cell or a battery. Do not store cells or batteries haphazardly in a box or drawer where they may short-circuit each other or be short-circuited by other metal objects.
- d) Do not remove a cell or battery from its original packaging until required for use.
- e) Do not subject cells or batteries to mechanical shock.
- f) In the event of a cell leaking, do not allow the liquid to come in contact with the skin or eyes. If contact has been made, wash the affected area with copious amounts of water and seek medical advice.
- g) Do not use any charger other than that specifically provided for use with the equipment.
- h) Observe the plus (+) and minus (-) marks on the cell, battery and equipment and ensure correct use.
- i) Do not use any cell or battery which is not designed for use with the equipment.
- j) Do not mix cells of different manufacture, capacity, size or type within a device.
- k) Battery usage by children should be supervised.
- l) Seek medical advice immediately if a cell or a battery has been swallowed.
- m) Always purchase the battery recommended by the device manufacturer for the equipment.
- n) Keep cells and batteries clean and dry.
- o) Wipe the cell or battery terminals with a clean dry cloth if they become dirty.
- p) Secondary cells and batteries need to be charged before use. Always use the correct charger and refer to the manufacturer's instructions or equipment manual for proper charging instructions.
- q) Do not leave a battery on prolonged charge when not in use.
- r) After extended periods of storage, it may be necessary to charge and discharge the cells or batteries several times to obtain maximum performance.
- s) Retain the original product literature for future reference.
- t) Use only the cell or battery in the application for which it was intended.
- u) When possible, remove the battery from the equipment when not in use.
- v) Dispose of properly.

Bibliography

IEC 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60485, *Digital electronic d.c. voltmeters and d.c. electronic analogue-to-digital convertors*¹

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

IEC 61434, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Guide to the designation of current in alkaline secondary cell and battery standards*

IEC 61438, *Possible safety and health hazards in the use of alkaline secondary cells and batteries - Guide to equipment manufacturers and users*

IEC/TR 62188, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Design and manufacturing recommendations for portable batteries made from sealed secondary cells*

IEC 62281, *Safety of primary and secondary lithium cells and batteries during transport*

United Nations, New York & Geneva, *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Chapter 38.3.*

¹ This publication was withdrawn.

<http://www.china-gauges.com/>

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards-based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process.

Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means - electronic, photocopying, recording or otherwise - without prior written permission from BSI. Details and advice can be obtained from the Copyright 8i Licensing Department.

Useful Contacts:

Customer Services

Tel: +44 845 086 9001

Email (orders): orders@bsigroup.com

Email (enquiries): cserices@bsigroup.com

Subscriptions

Tel: +44 845 086 9001

Email: subscriptions@bsigroup.com

Knowledge Centre

Tel: +44 20 8996 7004

Email: knowledgecentre@bsigroup.com

Copyright & Licensing

Tel: +44 20 8996 7070

Email: copyright@bsigroup.com

<http://www.china-gauges.com/>



...making excellence a habit!"