IEC 60086-1

Edition 12.0 2015-07

INTERNATIONAL STANDARD

Primary batteries –
Part 1: General

IEC 60086-1:2015-07(en)

International Electrotechnical Commission

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CONTENTS

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PRIMARY BATTERIES –

Part 1: General

FOREWORD

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International Standard IEC 60086-1 has been prepared by IEC technical committee 35: Primary cells and batteries.

This twelfth edition cancels and replaces the eleventh edition (2011) and constitutes a technical revision.

The major technical changes with respect to the previous edition are:

– the order of the Annexes was changed to the order in which they appear in the document and a caption was added to indicate where the Annex information first appears in the document;
– the humidity conditions for non P-system batteries in Table 3 was modified;
– the standard discharge voltage for the Y and W chemistries was determined to be at 3,5 V and 2,8 V respectively;
– details on capacity measurement were moved from Annex E to Subclause 5.1.

– the coin/button cell and battery definition was clarified in order to better address issues with the swallowing of coin cells.

The text of this standard is based on the following documents:

FDIS	Report on voting
35/1346/FDIS	35/1349/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60086 series, under the general title *Primary batteries*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

The technical content of this part of IEC 60086 provides fundamental requirements and information on primary cells and batteries. All batteries within the IEC 60086 series are considered dry cell batteries. In this sense, IEC 60086-1 is the main component of the IEC 60086 series and forms the basis for the subsequent parts. For example, this part includes elementary information on definitions, nomenclature, dimensions and marking. While specific requirements are included, the content of this part tends to explain methodology (how) and justification (why).

Over the years, this part has been changed to improve its content and remains under continual scrutiny to ensure that the publication is kept up to date with the advances in both battery and battery-powered device technologies.

NOTE Safety information is available in IEC 60086-4, IEC 60086-5 and IEC 62281.

PRIMARY BATTERIES –

Part 1: General

1 Scope

This part of IEC 60086 is intended to standardize primary batteries with respect to dimensions, nomenclature, terminal configurations, markings, test methods, typical performance, safety and environmental aspects.

As a primary battery classification tool, electrochemical systems are also standardized with respect to system letter, electrodes, electrolyte, nominal and maximum open circuit voltage.

NOTE The requirements justifying the inclusion or the ongoing retention of batteries in the IEC 60086 series are given in Annex A.

The object of this part of IEC 60086 is to benefit primary battery users, device designers and battery manufacturers by ensuring that batteries from different manufacturers are interchangeable according to standard form, fit and function. Furthermore, to ensure compliance with the above, this part specifies standard test methods for testing primary cells and batteries.

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 60086-2:–[1], *Primary batteries – Part 2: Physical and electrical specifications*

IEC 60086-3:2011, *Primary batteries – Part 3: Watch batteries*

IEC 60086-4:2014, *Primary batteries – Part 4: Safety of lithium batteries*

IEC 60086-5:2011, *Primary batteries – Part 5: Safety of batteries with aqueous electrolyte*

3 Terms and definitions

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

3.1
application test
simulation of the actual use of a battery in a specific application

3.2
battery
one or more cells electrically connected and fitted in a case, with terminals, markings and protective devices etc., as necessary for use

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1 To be published.

[SOURCE:IEC 60050-482:2004, 482-01-04, modified definition]

3.3
button (cell or battery)
small round cell or battery where the overall height is less than the diameter

Note 1 to entry: In English, the term “button (cell or battery)” is only used for non-lithium batteries while the term “coin (cell or battery)” is used for lithium batteries only. In languages other than English, the terms “coin” and “button” are often used interchangeably, regardless of the electrochemical system.

3.4
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:IEC 60050-482:2004, 482-01-01]

3.5
closed-circuit voltage
CCV (abbreviation)
voltage across the terminals of a battery when it is on discharge

[SOURCE:IEC 60050-482:2004, 482-03-28, modified ("voltage between the terminals of a cell or battery" replaced by "voltage across the terminals of a battery")]

3.6
coin (cell or battery)
see button (cell or battery)

3.7
cylindrical (cell or battery)
round cell or battery in which the overall height is equal to or greater than the diameter

[SOURCE:IEC 60050-482: 2004, 482-02-39, modified ("cell with a cylindrical shape" replaced by "round cell or battery")]

3.8
discharge (of a primary battery)
operation during which a battery delivers current to an external circuit

3.9
dry (primary) **battery**
primary battery in which the liquid electrolyte is essentially immobilized

[SOURCE:IEC 60050-482:2004, 482-04-14, modified]

3.10
effective internal resistance – DC method
the internal d.c. resistance of any electrochemical cell is defined by the following relation:

$$R_\mathrm{i}\ (\Omega) = \frac{\Delta U\ (\mathrm{V})}{\Delta i\ (\mathrm{A})}$$

3.11
end-point voltage
EV (abbreviation)
specified voltage of a battery at which the battery discharge is terminated

[SOURCE:IEC 60050-482:2004, 482-03-30]

3.12
leakage
unplanned escape of electrolyte, gas or other material from a cell or battery

[SOURCE:IEC 60050-482:2004, 482-02-32]

3.13
minimum average duration
MAD (abbreviation)
minimum average time on discharge which is met by a sample of batteries

Note 1 to entry: The discharge test is carried out according to the specified methods or standards and designed to show conformity with the standard applicable to the battery types.

3.14
nominal voltage (of a primary battery)
V_n (symbol)
suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system

[SOURCE:IEC 60050-482:2004, 482-03-31, modified (addition of "(of a primary battery)" and symbol V_n)]

3.15
open-circuit voltage
OCV (abbreviation)
voltage across the terminals of a cell or battery when it is off discharge

3.16
primary (cell or battery)
cell or battery that is not designed to be electrically recharged

3.17
round (cell or battery)
cell or battery with circular cross section

3.18
service output (of a primary battery)
service life, or capacity, or energy output of a battery under specified conditions of discharge

3.19
service output test
test designed to measure the service output of a battery

Note 1 to entry: A service output test may be prescribed, for example, when

a) an application test is too complex to replicate;

b) the duration of an application test would make it impractical for routine testing purposes.

3.20
small battery
cell or battery fitting entirely within the limits of the truncated cylinder as defined in Figure 1

Inner dimensions in millimetres (mm)

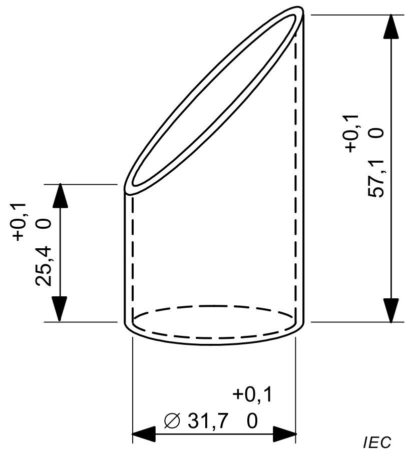

Figure 1 – Ingestion gauge

3.21
storage life
duration under specified conditions at the end of which a battery retains its ability to perform a specified service output

[SOURCE:IEC 60050-482:2004, 482-03-47, modified ("function" replaced by "service output")]

3.22
terminals (of a primary battery)
conductive parts of a battery that provide connection to an external circuit

4 Requirements

4.1 General

4.1.1 Design

Primary batteries are sold mainly in consumer markets. In recent years, they have become more sophisticated in both chemistry and construction, for example both capacity and rate capability have increased to meet the growing demands from new, battery-powered equipment technology.

When designing primary batteries, the aforementioned considerations shall be taken into account. Specifically, their dimensional conformity and stability, their physical and electrical performance and their safe operation under normal use and foreseeable mis-use conditions shall be assured.

Additional information on equipment design can be found in Annex B.

4.1.2 Battery dimensions

The dimensions for individual types of batteries are given in IEC 60086-2 and IEC 60086-3.

4.1.3 Terminals

4.1.3.1 General

Terminals shall be in accordance with Clause 6 of IEC 60086-2:−.

Their physical shape shall be designed in such a way that they ensure that the batteries make and maintain good electrical contact at all times.

They shall be made of materials that provide good electrical conductivity and resistance to corrosion.

4.1.3.2 Contact pressure resistance

Where stated in the battery specification tables or the individual specification sheets in IEC 60086-2, the following applies:

– a force of 10 N applied through a steel ball of 1 mm diameter at the centre of each contact area for a period of 10 s shall not cause any apparent deformation which might prevent satisfactory operation of the battery.

NOTE See also IEC 60086-3 for exceptions.

4.1.3.3 Cap and base

This type of terminal is used for batteries which have their dimensions specified according to Figures 1 to 7 of IEC 60086-2:− and which have the cylindrical side of the battery insulated from the terminals.

4.1.3.4 Cap and case

This type of terminal is used for batteries which have their dimensions specified according to Figures 8, 9, 10, 14, 15 and 16 of IEC 60086-2:−, but in which the cylindrical side of the battery forms part of the positive terminal.

4.1.3.5 Screw terminals

This contact consists of a threaded rod in combination with either a metal or insulated metal nut.

4.1.3.6 Flat contacts

These are essentially flat metal surfaces adapted to make electrical contact by suitable contact mechanisms bearing against them.

4.1.3.7 Flat or spiral springs

These contacts comprise flat metal strips or spirally wound wires which are in a form that provides pressure contact.

4.1.3.8 Plug-in-sockets

These are made up of a suitable assembly of metal contacts, mounted in an insulated housing or holding device and adapted to receive corresponding pins of a mating plug.

4.1.3.9 Snap fasteners

4.1.3.9.1 General

These contacts are composed of a combination comprising a stud (non-resilient) for the positive terminal and a socket (resilient) for the negative terminal.

They shall be of suitable metal so as to provide efficient electrical connection when joined to the corresponding parts of an external circuit.

4.1.3.9.2 Snap fastener

This type of terminal consists of a stud for the positive terminal and a socket for the negative terminal. These shall be made from nickel plated steel or other suitable material. They shall be designed to provide a secure physical and electrical connection, when fitted with similar corresponding parts for connection to an electrical circuit.

4.1.3.10 Wire

Wire leads may be single or multi-strand flexible insulated tinned copper. The positive terminal wire covering shall be red and the negative black.

4.1.3.11 Other spring contacts or clips

These contacts are generally used on batteries when the corresponding parts of the external circuit are not precisely known. They shall be of spring brass or of other material having similar properties.

4.1.4 Classification (electrochemical system)

Primary batteries are classified according to their electrochemical system.

Each system, with the exception of the zinc-ammonium chloride, zinc chloride-manganese dioxide system, has been allocated a letter denoting the particular system.

The electrochemical systems that have been standardized up to now are given in Table 1.

Table 1 – Standardized electrochemical systems

Letter	Negative electrode	Electrolyte	Positive electrode	Nominal voltage V	Maximum open circuit voltage V
No letter	Zinc (Zn)	Ammonium chloride, Zinc chloride	Manganese dioxide (MnO_2)	1,5	1,73
A	Zinc (Zn)	Ammonium chloride, Zinc chloride	Oxygen (O_2)	1,4	1,55
B	Lithium (Li)	Organic electrolyte	Carbon monofluoride $(CF)_x$	3,0	3,7
C	Lithium (Li)	Organic electrolyte	Manganese dioxide (MnO_2)	3,0	3,7
E	Lithium (Li)	Non-aqueous inorganic	Thionyl chloride ($SOCl_2$)	3,6	3,9
F	Lithium (Li)	Organic electrolyte	Iron disulfide (FeS_2)	1,5	1,83
G	Lithium (Li)	Organic electrolyte	Copper (II) oxide (CuO)	1,5	2,3
L	Zinc (Zn)	Alkali metal hydroxide	Manganese dioxide (MnO_2)	1,5	1,68
P	Zinc (Zn)	Alkali metal hydroxide	Oxygen (O_2)	1,4	1,59
S	Zinc (Zn)	Alkali metal hydroxide	Silver oxide (Ag_2O)	1,55	1,63
W	Lithium (Li)	Organic electrolyte	Sulphur dioxide (SO_2)	3,0	3,05
Y	Lithium (Li)	Non-aqueous inorganic	Sulfuryl chloride (SO_2Cl_2)	3,9	4,1
Z	Zinc (Zn)	Alkali metal hydroxide	Nickel oxyhydroxide (NiOOH)	1,5	1,78

NOTE 1 The value of the nominal voltage is not verifiable; therefore it is only given as a reference.

NOTE 2 The maximum open-circuit voltage (3.15) is measured as defined in 5.5 and 6.8.1.

NOTE 3 When referring to an electrochemical system, common protocol is to list negative electrode first, followed by positive electrode, i.e. lithium-iron disulfide.

4.1.5 Designation

The designation of primary batteries is based on their physical parameters, their electrochemical system as well as modifiers, if needed.

A comprehensive explanation of the designation system (nomenclature) can be found in Annex C.

4.1.6 Marking

4.1.6.1 General (see Table 2)

With the exception of small batteries (see 4.1.6.2), each battery shall be marked with the following information:

a) designation, IEC or common;
b) expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code;
c) polarity of the positive (+) terminal;
d) nominal voltage;
e) name or trade mark of the manufacturer or supplier;
f) cautionary advice.

NOTE Examples of the common designations can be found in Annex D of IEC 60086-2:–.

4.1.6.2 Marking of small batteries (see Table 2)

a) Batteries designated in the IEC as small, mainly category 3 and category 4 batteries have a surface too small to accommodate all markings shown in 4.1.6.1. For these batteries the designation 4.1.6.1a) and the polarity 4.1.6.1c) shall be marked on the battery. All other markings shown in 4.1.6.1 may be given on the immediate packing instead of on the battery.
b) For P-system batteries, 4.1.6.1a) may be on the battery, the sealing tab or the package.4.1.6.1c) may be marked on the sealing tab and/or on the battery. 4.1.6.1b), 4.1.6.1d) and 4.1.6.1e) may be given on the immediate packing instead of on the battery.
c) Caution for ingestion of swallowable batteries shall be given. Refer to IEC 60086-4:2014 (7.2 a) and 9.2) and IEC 60086-5:2011 (7.1 l) and 9.2) for details.

Table 2 – Marking requirements

Marking		Batteries with the exception of small batteries	Small batteries	
				P-system batteries
a)	Designation, IEC or common	A	A	C
b)	Expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code	A	B	B
c)	Polarity of the positive (+) terminal	A	A	D
d)	Nominal voltage	A	B	B
e)	Name or trade mark of the manufacturer or supplier	A	B	B
f)	Cautionary advice	A	B[a]	B[a]

A: shall be marked on the battery

B: may be marked on the immediate packing instead on the battery

C: may be marked on the battery, the sealing tab or the immediate packing

D: may be marked on the sealing tab and/or on the battery

[a] Caution for ingestion of swallowable batteries shall be given. Refer to IEC 60086-4:2014 (7.2a) and 9.2) and IEC 60086-5:2011 (7.1l) and 9.2) for details.

4.1.6.3 Marking of batteries regarding method of disposal

Marking of batteries with respect to the method of disposal shall be in accordance with local legal requirements.

4.1.7 Interchangeability: battery voltage

Primary batteries as presently standardized in the IEC 60086 series can be categorized by their standard discharge voltage U_s[2]. For a new battery system, its interchangeability by voltage is assessed for compliance with the following formula:

$$n \times 0{,}85\ U_r \leq m \times U_s \leq n \times 1{,}15\ U_r$$

where

n is the number of cells connected in series, based on reference voltage U_r;

m is the number of cells connected in series, based on standard discharge voltage U_s.

Currently, two voltage ranges that conform to the above formula have been identified. They are identified by reference voltage U_r, which is the midpoint of the relevant voltage range.

Voltage range 1, U_r = 1,4 V: Batteries having a standard discharge voltage $m \times U_s$ equal to or within the range of $n \times 1{,}19$ V to $n \times 1{,}61$ V.

Voltage range 2, U_r = 3,2 V: Batteries having a standard discharge voltage $m \times U_s$ equal to or within the range of $n \times 2{,}72$ V to $n \times 3{,}68$ V.

The term standard discharge voltage and related quantities, as well as the methods of their determination, are given in Annex D.

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2 The standard discharge voltage U_s was introduced to comply with the principle of experimental verifiability. Neither the nominal voltage nor the maximum off-load voltage complies with this requirement.

NOTE For single-cell batteries and for multi-cell batteries assembled with cells of the same voltage range, m and n will be identical; m and n will be different for multi-cell batteries if assembled with cells from a different voltage range than those of an already standardized battery.

Voltage range 1 encompasses all presently standardized batteries with a nominal voltage of 1,5 V, i.e. "no-letter" system, systems A, F, G, L, P, S and Z.

Voltage range 2 encompasses all presently standardized batteries with a nominal voltage of 3 V, i.e. systems B, C, E, W and Y.

Because batteries from voltage range 1 and voltage range 2 show significantly different discharge voltages, they shall be designed to be physically non-interchangeable. Before standardizing a new electrochemical system, its standard discharge voltage shall be determined in accordance with the procedure given in Annex D to resolve its interchangeability by voltage.

WARNING Failure to comply with this requirement can present safety hazards to the user, such as fire, explosion, leakage and/or device damage. This requirement is necessary for safety and operational reasons.

4.2 Performance

4.2.1 Discharge performance

Discharge performance of primary batteries is specified in IEC 60086-2.

4.2.2 Dimensional stability

The dimensions of batteries shall conform with the relevant specified dimensions as given in IEC 60086-2 and IEC 60086-3 at all times during discharge testing under the standard conditions given in this specification.

NOTE 1 An increase in battery height of 0,25 mm can occur with button cells of the B, C, G, L, P and S systems, if discharged below end-point voltage.

NOTE 2 For certain button cells (coin cells) of the C and B systems, a decrease in battery height may occur as discharge continues.

4.2.3 Leakage

When batteries are stored and discharged under the standard conditions given in this specification, no leakage shall occur.

4.2.4 Open-circuit voltage limits

The maximum open-circuit voltage of batteries shall not exceed the values given in Table 1.

4.2.5 Service output

Discharge durations, initial and delayed, of batteries shall meet the requirements given in IEC 60086-2.

4.2.6 Safety

When designing primary batteries, safety under conditions of intended use and foreseeable mis-use as prescribed in IEC 60086-4 and IEC 60086-5 shall be considered.

5 Performance – Testing

5.1 General

For the preparation of standard methods of measuring performance (SMMP) of consumer goods, refer to Annex E.

A capacity of a primary battery may be established by electrical discharge tests as detailed in D.2.3. However, under consumer usage conditions, the capacities realised from electrical discharge test methods can vary.

The following factors/variables dramatically impact on optimum capacity realisation.

a) The current demand from the external electrical circuit/device.
b) The frequency of current demand. (Continuous or intermittent usage).
c) The minimum voltage at which the device will satisfactorily operate. (Cut off voltage).
d) The temperature of operation.

From the variables listed in a) to d), high current demand for prolonged periods coupled with a high cut off voltage and low temperature represent the worst case conditions resulting in significant capacity loss.

Because the electrically or chemically derived capacity of a primary battery cannot be reliably used in any calculation of ultimate battery performance it is nevertheless essential to convey to the user some idea of battery performance/life when used in typical battery powered devices. It should however be noted that such designated ‘application tests’ (defined in 60086-2) may not entirely replicate a device/application there being many variations each with differing electrical requirements in the marketplace. Furthermore battery performance may be further affected by one or more of the conditions in a) to d) above.

The following has therefore been derived from ISO/IEC Guide 36:1982.

5.2 Discharge testing

5.2.1 General

The discharge tests in this standard fall into two categories:

– application tests;
– service output tests.

In both categories of tests, discharge loads are specified in accordance with 6.4.

The test methods of determining the load and test conditions are as given in 5.2.2 .

5.2.2 Application tests

5.2.2.1 General

a) The equivalent resistance is calculated from the average current and average operating voltage of the equipment under load. Constant current or constant power loads are also permitted for applications exhibiting these types of power demand patterns.
b) The functional end-point voltage and the equivalent resistance load, current load, or constant power values are obtained from typical application equipment measurements.
c) The median class defines the load value and the end-point voltage to be used for the discharge test.
d) If the data are concentrated in two or more widely separated groups, more than one test may be required.

Application tests may be accelerated by discharge load, daily period duty cycle, or both. The specified values for load and time intermittency should take the following factors into consideration:

– discharge efficiency of the battery relative to the application.
– typical duty cycle use patterns for the application.
– total time to conduct the test not to exceed 30 days.

Some fixed resistance tests have been chosen to permit simplicity of design and ensure reliability of the test equipment, despite the fact that, in specific instances, constant current or constant wattage tests may be a better representation of the application.

In the future, alternative or additional load conditions may be necessary to effectively represent the range of applications in use. It is likely that the load characteristics of a particular category of equipment will change with time in a developing technology.

The precise determination of the functional end-point voltage of the equipment is not always possible. The discharge conditions are at best a compromise selected to represent a category of equipment which may have widely divergent characteristics.

Nevertheless, in spite of these limitations, the derived application test is the best approach known for the estimation of battery capability for a particular category of equipment.

NOTE In order to minimize the proliferation of application tests, the tests specified target to be those accounting for 80 % of the market by battery designation.

5.2.2.2 Application tests with multiple loads

For application test with multiple loads, the load order during a cycle shall start with the heaviest load and move to the lightest load unless otherwise specified.

5.2.3 Service output tests

For service output tests, the value of the load resistor should be selected such that the service output approximates 30 days.

When full capacity is not realized within the required time scale, the service output may be extended to the shortest suitable duration thereafter by selecting a discharge load of higher ohmic value, as defined in 6.4.

5.3 Conformance check to a specified minimum average duration

In order to check the conformance of a battery to any discharge tests specified in IEC 60086-2 and 60086-3, the test shall be carried out as follows:

a) Test eight batteries.
b) Calculate the average without the exclusion of any result.
c) If this average is equal to or greater than the specified figure and no more than one battery has a service output of less than 80 % of the specified figure, the batteries are considered to conform to service output.
d) If this average is less than the specified figure and/or more than one battery has a service output of less than 80 % of the specified figure, repeat the test on another sample of eight batteries and calculate the average as previously.
e) If the average of this second test is equal to or greater than the specified figure and no more than one battery has a service output of less than 80 % of the specified figure, the batteries are considered to conform to service output.

f) If the average of the second test is less than the specified figure and/or more than one battery has a service output of less than 80 % of the specified figure, the batteries are considered not to conform and no further testing is permitted.

g) For the purposes of verifying compliance with this standard, conditional acceptance may be given after completion of the initial discharge tests.

NOTE Discharge performance of primary batteries is specified in IEC 60086-2.

5.4 Calculation method of the specified value of a minimum average duration

This method is described in Annex F.

5.5 OCV testing

Open-circuit voltage shall be measured with the voltage measuring equipment specified in 6.8.1.

5.6 Battery dimensions

Dimensions shall be measured with the measuring equipment specified in 6.8.2.

5.7 Leakage and deformation

After the service output has been determined under the specified environmental conditions, the discharge shall be continued in the same way until the closed circuit voltage drops for the first time below 40 % of the nominal voltage of the battery. The requirements of 4.1.3, 4.2.2 and 4.2.3 shall be met.

NOTE For watch batteries, the visual examination for leakage is carried out in accordance with Clause 8 of IEC 60086-3:2011.

6 Performance – Test conditions

6.1 Storage and discharge conditions

Storage before discharge testing and the actual discharge test is carried out under well-defined conditions. Unless otherwise specified, the conditions given in Table 3 shall apply. Discharge conditions shown are further referred to as standard conditions.

Table 3 – Conditions for storage before and during discharge testing

Type of test	Storage conditions			Discharge conditions	
	Temperature °C	Relative humidity % RH	Duration	Temperature °C	Relative humidity[d] % RH
Initial discharge test	20 ± 2 [a]	55 ± 20	60 days maximum after date of manufacture	20 ± 2	55 +20 / -40
Delayed discharge test	20 ± 2 [a]	55 ± 20	12 months	20 ± 2	55 +20 / -40
Delayed discharge test (high temperature) [b]	45 ± 2 [c]	55 ± 20	13 weeks	20 ± 2	55 +20 / -40

[a] During short periods the storage temperature may deviate from these limits without exceeding (20 ± 5) °C.

[b] This test is carried out when a storage test at high temperature is required. Performance requirements are the subject of agreement between the manufacturer and the customer.

[c] Batteries to be stored unpacked.

[d] Except “P” system: (55 ± 10) % RH.

6.2 Commencement of discharge tests after storage

The period between the completion of storage and the start of a delayed discharge test shall not exceed 14 days.

During this period the batteries shall be kept at (20 ± 2) °C and (55 + 20 / -40) % RH (except for P-system batteries where the relative humidity shall be (55 ± 10) % RH).

At least one day in these conditions shall be allowed for normalization before starting a discharge test after storage at high temperature.

6.3 Discharge test conditions

6.3.1 General

In order to test a battery it shall be discharged as specified in IEC 60086-2 or IEC 60086-3 until the voltage on load drops for the first time below the specified end-point. The service output may be expressed as pulses, duration, capacity, or energy.

6.3.2 Compliance

When IEC 60086-2 or IEC 60086-3 specify service outputs for more than one discharge test, batteries shall meet all of these requirements in order to comply with this specification.

6.4 Load resistance

The value of the resistive load (which includes all parts of the external circuit) shall be as specified in the relevant specification sheet and shall be accurate to ± 0,5 %.

When formulating new tests, the resistive load shall, whenever possible, be as shown in Table 4 together with their decimal multiples or sub-multiples.

Table 4 – Resistive loads for new tests

Values in ohms

1,00	1,10	1,20	1,30	1,50	1,60	1,80	2,00
2,20	2,40	2,70	3,00	3,30	3,60	3,90	4,30
4,70	5,10	5,60	6,20	6,80	7,50	8,20	9,10

6.5 Time periods

The periods on-discharge and off-discharge shall be as specified in IEC 60086-2.

When formulating new tests, whenever possible, one of the following daily periods should be adopted from Table 5.

Table 5 – Time periods for new tests

1 min	5 min	10 min	30 min	1 h
2 h	4 h	12 h	24 h (continuous)	--

Other cases are specified in IEC 60086-2, if necessary.

6.6 Test condition tolerances

Unless otherwise specified, the tolerances given in Table 6 shall apply.

Table 6 – Test condition tolerances

Test parameter	Tolerance	
Temperature	± 2 °C	
Load	± 0,5 %	
Voltage	± 0,5 %	
Relative humidity	+20 / -40 % RH except 'P' system ± 10 % RH	
Time “accuracy”	**Discharge time t_d**	**Tolerance**
	$0 < t_d \le 2$ s	± 5 % of t_d
	$2\ s < t_d \le 100$ s	± 0,1 s
	$t_d > 100$ s	± 0,1 % of t_d

6.7 Activation of ‘P’-system batteries

A period of at least 10 min shall elapse between activation and the commencement of electrical measurement.

6.8 Measuring equipment

6.8.1 Voltage measurement

The accuracy of the measuring equipment shall be ≤ 0,25 % and the precision shall be ≤ 50 % of the value of the last significant digit. The internal resistance of the measuring instrument shall be ≥1 MΩ.

6.8.2 Mechanical measurement

The accuracy of the measuring equipment shall be ≤ 0,25 % and the precision shall be ≤ 50 % of the value of the last significant digit.

7 Sampling and quality assurance

The use of sampling plans or product quality indices should be agreed between the manufacturer and the purchaser.

Where no agreement is specified, refer to ISO 2859 and ISO 21747 for sampling and quality compliance assessment advice.

8 Battery packaging

A code of practice for battery packaging, shipment, storage, use and disposal can be found in Annex G.

Annex A
(normative)

Criteria for the standardization of batteries

Batteries and electrochemical systems shall meet the following requirements to justify their initial inclusion or ongoing retention in the IEC 60086 series:

a) The battery or batteries of this electrochemical system are in mass production.

b) The battery or batteries of this electrochemical system are available in several market places of the world.

c) The battery is produced by at least two independent manufacturers, the patent holder(s) of which shall conform to the requirements contained in 2.14 of the ISO/IEC Directives, Part 1, Reference to patented items.

d) The battery is produced in at least two different countries or, alternatively, the battery is purchased by other international and independent battery manufacturers and sold under their company label.

The items of Table A.1 shall be included in any new work proposal to standardize a new individual battery or electrochemical system.

Table A.1 – Items necessary to standardize

Individual battery	Electrochemical system
Conformance statement to items a) to d) above	Conformance statement to items a) and b) above
Designation and electrochemical system	Recommended designation letter
Dimensions (including drawings)	Negative electrode
Discharge conditions	Positive electrode
Minimum average duration(s)	Nominal voltage
	Maximum open circuit voltage
	Electrolyte

Annex B
(informative)

Recommendations for equipment design

B.1 Technical liaison

It is recommended that companies producing battery-powered equipment maintain close liaison with the battery industry. The capabilities of existing batteries should be taken into account at design inception. Whenever possible, the battery type selected should be one included in IEC 60086-2. The equipment should be permanently marked with the IEC designation, grade and size of battery which will give optimum performance.

B.2 Battery compartment

B.2.1 General

Design compartments so that batteries are easily inserted and do not fall out. The dimensions and design of compartments and contacts should be such that batteries complying with this standard will be accepted. In particular, the equipment designer should not ignore the tolerances given in this standard, even if a national standard or a battery manufacturer calls for smaller battery tolerances.

The design of the negative contact should make allowance for any recess of the battery terminal.

Clearly indicate the type of battery to use, the correct polarity alignment and directions for insertion.

Use the shape and/or the dimensions of the positive (+) and negative (–) battery terminals in compartment designs to prevent the reverse connection of batteries. Positive (+) and negative (–) battery contacts should be visibly different in form to avoid confusion when inserting batteries.

Battery compartments should be electrically insulated from the electric circuit and positioned so as to minimize possible damage and/or risk of injury. Only the battery terminals should physically contact the electric circuit. Care should be taken in the choice of materials and the design of contacts to ensure that effective electrical contact is made and maintained under conditions of use even with batteries at the extremes of dimensions permitted by this standard. Battery and equipment terminals should be of compatible material and low electrical resistance.

Battery compartments with parallel connections are not recommended since a wrongly placed battery will result in charging conditions.

Equipment designed to be powered by air-depolarized batteries of either the "A" or "P" system shall provide for adequate air access. For the "A" system, the battery should preferably be in an upright position during normal operation. For "P" system batteries conforming to Figure 9 of IEC 60086-2:−, positive contact should be made on the side of the battery, so that air access is not impeded.

Although batteries are very much improved regarding their resistance to leakage, it can still occur occasionally. When the battery compartment cannot be completely isolated from the equipment, it should be positioned so as to minimize possible damage.

The battery compartment should be clearly and permanently marked to show the correct orientation of the batteries. One of the most common causes of dissatisfaction is the reversed placement of one battery in a set, which may result in battery leakage and/or explosion and/or fire. To minimize this hazard, battery compartments should be designed so that a reversed battery will result in no electrical circuit.

The associated circuitry should not make physical contact with any part of the battery except at the surfaces intended for this purpose.

Designers are strongly advised to refer to IEC 60086-4 and IEC 60086-5 for comprehensive safety considerations.

B.2.2 Limiting access by children

Apparatus should be designed to prevent children from removing the battery by one of the following methods:

A tool, such as a screwdriver or coin, is required to open the battery compartment; or

The battery compartment door/cover requires the application of a minimum of two independent and simultaneous movements of the securing mechanism to open by hand.

If screws or similar fasteners are used to secure the door/cover providing access to the battery compartment, the fasteners should be captive to ensure that they remain with the door/cover. This does not apply to side panel doors on larger devices which are necessary for the functioning of the equipment and which are not likely to be discarded or left off the equipment.

B.3 Voltage cut-off

In order to prevent leakage resulting from a battery being driven into reverse, the equipment voltage cut-off should not be below the battery manufacturers' recommendation.

Annex C
(normative)

Designation system (nomenclature)

C.1 General

The battery designation system (nomenclature) defines as unambiguously as possible the physical dimensions, shape, electrochemical system, nominal voltage and, where necessary, the type of terminals, rate capability and special characteristics.

This annex is divided into two clauses:

– Clause C.2 defines the designation system (nomenclature) in use up to October 1990.
– Clause C.3 defines the designation system (nomenclature) in use since October 1990 to accommodate present and future needs.

C.2 Designation system in use up to October 1990

C.2.1 General

This clause applies to all batteries which have been standardized up to October 1990 and will remain valid for those batteries after that date.

C.2.2 Cells

A cell is designated by a capital letter followed by a number. The letters R, F and S define round, flat (layer built) and square cells, respectively. The letter, together with the following number[3], is defined by a set of nominal dimensions.

Where a single-cell battery is specified, the maximum dimensions of the battery instead of the nominal dimensions of the cell are given in Tables C.1, C.2 and C.3. Note that these tables do not include electrochemistries, except for the no letter system, or other modifiers. These other parts of the designation system (nomenclature) follow in C.2.3, C.2.4 and C.2.5. These tables only provide core physical designations for single cells or single batteries.

NOTE The complete dimensions of these batteries are given in IEC 60086-2 and IEC 60086-3.

3 At the time this system was applied, numbers were allocated sequentially. Omissions in the sequence arise because of deletions or by the different approach to numbering used even before the sequential system.

Table C.1 – Physical designation and dimensions of round cells and batteries

Dimensions in millimetres

Physical designation	Nominal cell dimensions		Maximum battery dimensions	
	Diameter	Height	Diameter	Height
R06	10	22	–	–
R03	–	–	10,5	44,5
R01	–	–	12,0	14,7
R0	11	19	–	–
R1	–	–	12,0	30,2
R3	13,5	25	–	–
R4	13,5	38	–	–
R6	–	–	14,5	50,5
R9	–	–	16,0	6,2
R10	–	–	21,8	37,3
R12	–	–	21,5	60,0
R14	–	–	26,2	50,0
R15	24	70	–	–
R17	25,5	17	–	–
R18	25,5	83	–	–
R19	32	17	–	–
R20	–	–	34,2	61,5
R22	32	75	–	–
R25	32	91	–	–
R26	32	105	–	–
R27	32	150	–	–
R40	–	–	67,0	172,0
R41	–	–	7,9	3,6
R42	–	–	11,6	3,6
R43	–	–	11,6	4,2
R44	–	–	11,6	5,4
R45	9,5	3,6	–	–
R48	–	–	7,9	5,4
R50	–	–	16,4	16,8
R51	16,5	50,0	–	–
R52	–	–	16,4	11,4
R53	–	–	23,2	6,1
R54	–	–	11,6	3,05
R55	–	–	11,6	2,1
R56	–	–	11,6	2,6
R57	–	–	9,5	2,7
R58	–	–	7,9	2,1
R59	–	–	7,9	2,6
R60	–	–	6,8	2,15
R61	7,8	39	–	–
R62	–	–	5,8	1,65
R63	–	–	5,8	2,15
R64	–	–	5,8	2,70
R65	–	–	6,8	1,65
R66	–	–	6,8	2,60
R67	–	–	7,9	1,65

Physical designation	Nominal cell dimensions		Maximum battery dimensions	
	Diameter	Height	Diameter	Height
R68	–	–	9,5	1,65
R69	–	–	9,5	2,10
R70	–	–	5,8	3,6
NOTE The complete dimensions of these batteries are given in IEC 60086-2 and IEC 60086-3.				

Table C.2 – Physical designation and nominal overall dimensions of flat cells

Dimensions in millimetres

Physical designation	Diameter	Length	Width	Thickness
F15	-	14,5	14,5	3,0
F16	-	14,5	14,5	4,5
F20	-	24	13,5	2,8
F22	-	24	13,5	6,0
F24	23	–	–	6,0
F25	-	23	23	6,0
F30	-	32	21	3,3
F40	-	32	21	5,3
F50	-	32	32	3,6
F70	-	43	43	5,6
F80	-	43	43	6,4
F90	-	43	43	7,9
F92	-	54	37	5,5
F95	-	54	38	7,9
F100	-	60	45	10,4
NOTE The complete dimensions of these batteries are given in IEC 60086-2.				

Table C.3 – Physical designation and dimensions of square cells and batteries

Dimensions in millimetres

Physical designation	Nominal cell dimensions			Maximum battery dimensions		
	Length	Width	Height	Length	Width	Height
S4	–	–	–	57,0	57,0	125,0
S6	57	57	150	–	–	–
S8	–	–	–	85,0	85,0	200,0
S10	95	95	180	–	–	–
NOTE The complete dimensions of these batteries are given in IEC 60086-2.						

In some cases, cell sizes which are not used in IEC 60086-2 have been retained in these tables because of their use in national standards.

C.2.3 Electrochemical system

With the exception of the zinc-ammonium chloride, zinc chloride-manganese dioxide system, the letters R, F and S are preceded by an additional letter which denotes the electrochemical system. These letters can be found in Table 1.

C.2.4 Batteries

If a battery contains one cell only, the cell designation is used.

If a battery contains more than one cell in series, a numeral denoting the number of cells precedes the cell designation.

If cells are connected in parallel, a numeral denoting the number of parallel groups follows the cell designation and is connected to it by a hyphen.

If a battery contains more than one section, each section is designated separately, with a slash (/) separating their designation.

C.2.5 Modifiers

In order to preserve the unambiguity of the battery designation, variants of one basic type are differentiated by the addition of a letter X or Y to indicate the different arrangements or terminals and P or S to indicate different performance characteristics.

C.2.6 Examples

R20 A battery consisting of a single R20-size cell of the zinc-ammonium chloride, zinc chloride-manganese dioxide system.

LR20 A battery consisting of a single R20-size cell of the zinc-alkali metal hydroxide-manganese dioxide system.

3R12 A battery consisting of three R12-size cells of the zinc-ammonium chloride, zinc chloride-manganese dioxide system, connected in series.

4R25X A battery consisting of four R25-size cells of the zinc-ammonium chloride, zinc chloride-manganese dioxide system, connected in series and with spiral spring contacts.

C.3 Designation system in use since October 1990

C.3.1 General

This clause applies to all new sizes considered for standardization after October 1990.

The basis for this designation system (nomenclature) is to convey a mental concept of the battery through the designation system. This is accomplished by using a diameter, from a cylindrical envelope, and a height related concept for all batteries, round (R) and non-round (P).

This clause also applies to single-cell batteries and multi-cell batteries with cells in series and/or parallel connection.

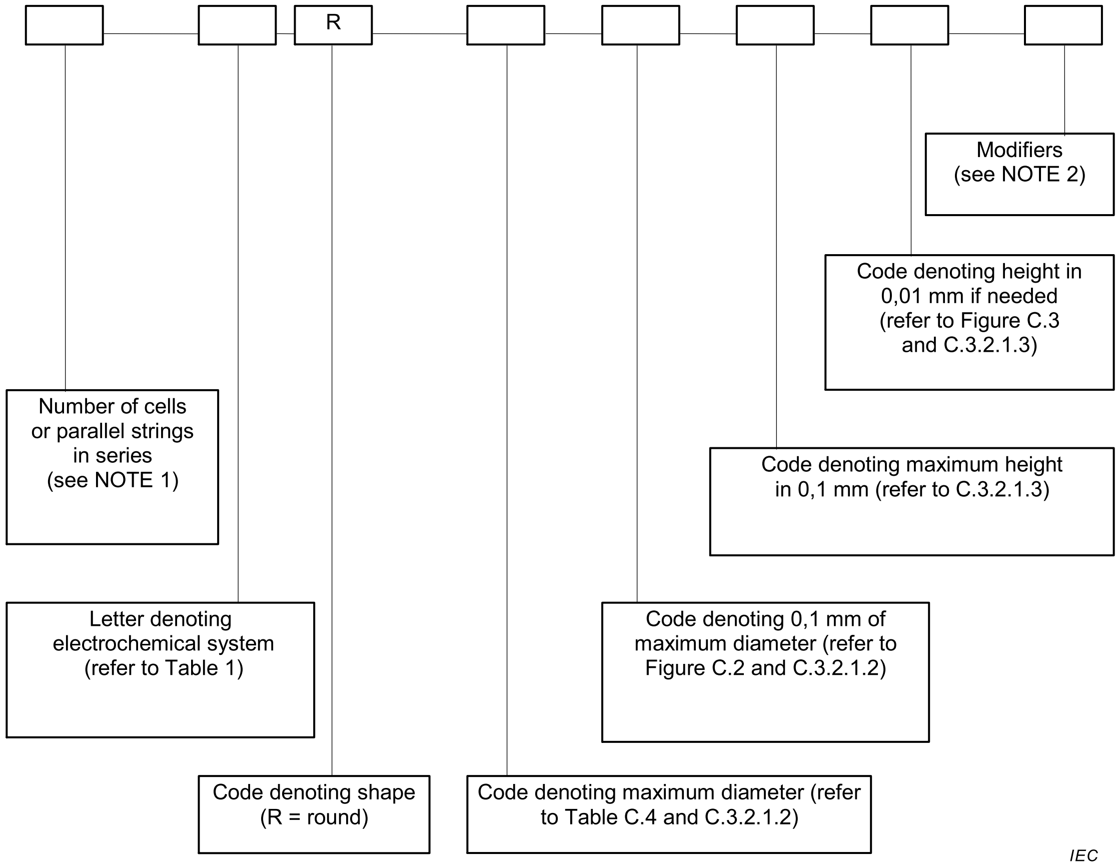
For example a battery of maximum diameter 11,6 mm and a height of maximum 5,4 mm is designated as R1154 preceded by a code for its electrochemical system, as described in this clause.

C.3.2 Round batteries

C.3.2.1 Round batteries with diameter and height less than 100 mm

C.3.2.1.1 General

The designation for round batteries with a diameter and height less than 100 mm is as shown in Figure C.1.



NOTE 1 The number of cells or strings in parallel is not specified.

NOTE 2 Modifiers are included to designate for example specific terminal arrangement, load capability and further special characteristics.

Figure C.1 – Designation system for round batteries:
d_1 < 100 mm; height h_1 < 100 mm

C.3.2.1.2 Method for assigning the diameter code

The diameter code is derived from the maximum diameter.

The diameter code number is:

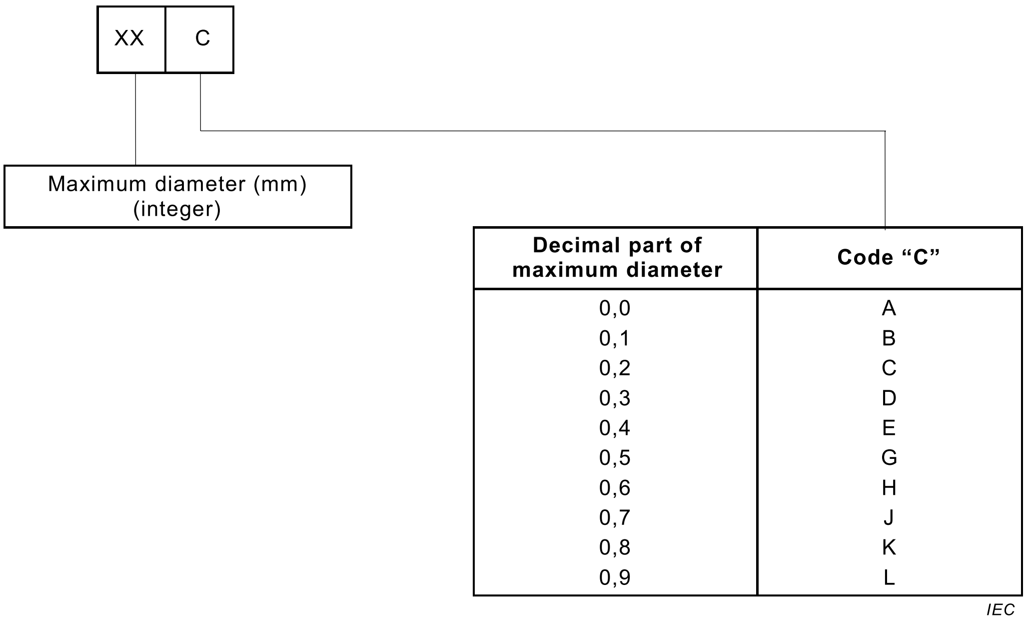
a) assigned according to Table C.4 in case of a recommended diameter;

b) assigned according to Figure C.2 in case of a non-recommended diameter.

Table C.4 – Diameter code for recommended diameter

Dimensions in millimetres

Code	Recommended maximum diameter	Code	Recommended maximum diameter
4	4,8	20	20,0
5	5,8	21	21,0
6	6,8	22	22,0
7	7,9	23	23,0
8	8,5	24	24,5
9	9,5	25	25,0
10	10,0	26	26,2
11	11,6	28	28,0
12	12,5	30	30,0
13	13,0	32	32,0
14	14,5	34	34,2
15	15,0	36	36,0
16	16,0	38	38,0
17	17,0	40	40,0
18	18,0	41	41,0
19	19,0	67	67,0



Decimal part of maximum diameter	Code "C"
0,0	A
0,1	B
0,2	C
0,3	D
0,4	E
0,5	G
0,6	H
0,7	J
0,8	K
0,9	L

Figure C.2 – Diameter code for non-recommended diameters

C.3.2.1.3 Method for assigning the height code

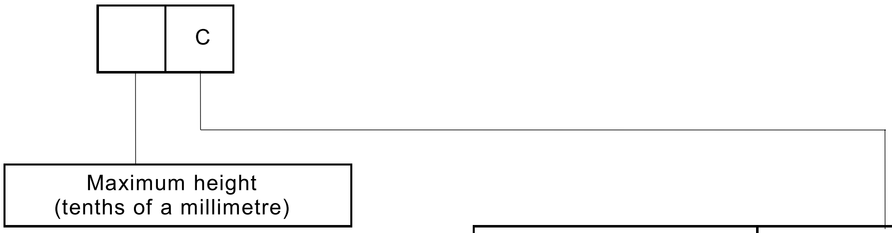
The height code is the number, denoted by the integer of the maximum height of the battery, expressed in tenths of a millimetre (e.g. 3,2 mm maximum height is denoted 32).

The maximum height is specified as follows:

a) for flat contact terminals, the maximum height is the overall height including the terminals;

b) for all other types of terminals, the maximum height is the maximum overall height excluding the terminals (i.e. shoulder-to-shoulder).

If the height in hundredths of a millimetre needs to be specified, the hundredth of a millimetre may be denoted by a code according to Figure C.3.



Decimal part of height mm	**Code "C"**
0,00	A
0,01	B
0,02	C
0,03	D
0,04	E
0,05	G
0,06	H
0,07	J
0,08	K
0,09	L

IEC

NOTE The hundredths of a millimetre code is only used when needed.

EXAMPLE 1 LR1154: A battery consisting of a round cell or string in parallel with a maximum diameter of 11,6 mm (Table C.4), and a maximum height of 5,4 mm, of the zinc-alkali metal hydroxide-manganese dioxide system.

EXAMPLE 2 LR27A116: A battery consisting of a round cell or string in parallel with a maximum diameter of 27 mm (Figure C.2) and a maximum height of 11,6 mm, of the zinc-alkali metal hydroxide-manganese dioxide system.

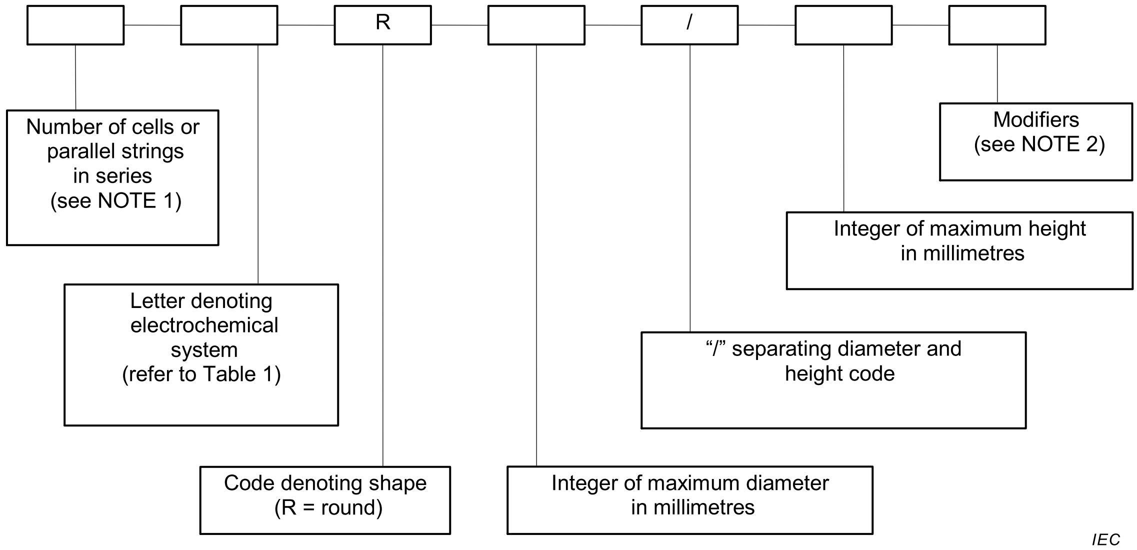
EXAMPLE 3 LR2616J: A battery consisting of a round cell or string in parallel with a maximum diameter of 26,2 mm (Table C.4), and a maximum height of 1,67 mm (Figure C.3), of the zinc-alkali metal hydroxide-manganese dioxide system.

Figure C.3 – Height code for denoting the hundredths of a millimetre of height

C.3.2.2 Round batteries with diameter and/or height over or equal to 100 mm

C.3.2.2.1 General

The designation for round batteries with a diameter and/or height ≥ 100 mm is as shown in Figure C.4.



NOTE 1 The number of cells or strings in parallel is not identified.

NOTE 2 Modifiers are included to designate for example specific terminal arrangement, load capability and further special characteristics.

Figure C.4 – Designation system for round batteries: $d_1 \geq 100$ mm; height $h_1 \geq 100$ mm

C.3.2.2.2 Method for assigning the diameter code

The diameter code is derived from the maximum diameter.

The diameter code number is the integer of the maximum diameter of the battery expressed in millimetres.

C.3.2.2.3 Method for assigning the height code

The height code is the number denoting the integer of the maximum height of the battery, expressed in millimetres.

The maximum height is specified as follows:

a) for flat contact terminals (e.g. batteries according to Figures 1, 7, 8 and 9 of IEC 60086-2:−), the maximum height is the overall height including the terminals;
b) for all other types of terminals, the maximum height is the maximal overall height excluding the terminals (i.e. shoulder-to-shoulder).

EXAMPLE 5R184/177: A round battery consisting of five cells or strings in parallel of the zinc-ammonium chloride, zinc chloride-manganese dioxide system, connected in series, having a diameter of 184,0 mm and a shoulder-to-shoulder maximum height of 177,0 mm.

C.3.3 Non-round batteries

C.3.3.1 General

The designation system for non-round batteries is as follows:

An imaginary cylindrical envelope is drawn, encompassing the surface from which the terminals first emerge from the battery case.

Using the maximum dimensions of length (l) and width (w), the diagonal is calculated, which is also the diameter of the imaginary cylinder.

For the designation, the integer of the diameter of the cylinder in millimetres and the integer of the maximum height of the battery in millimetres is applied.

The maximum height is specified as follows:

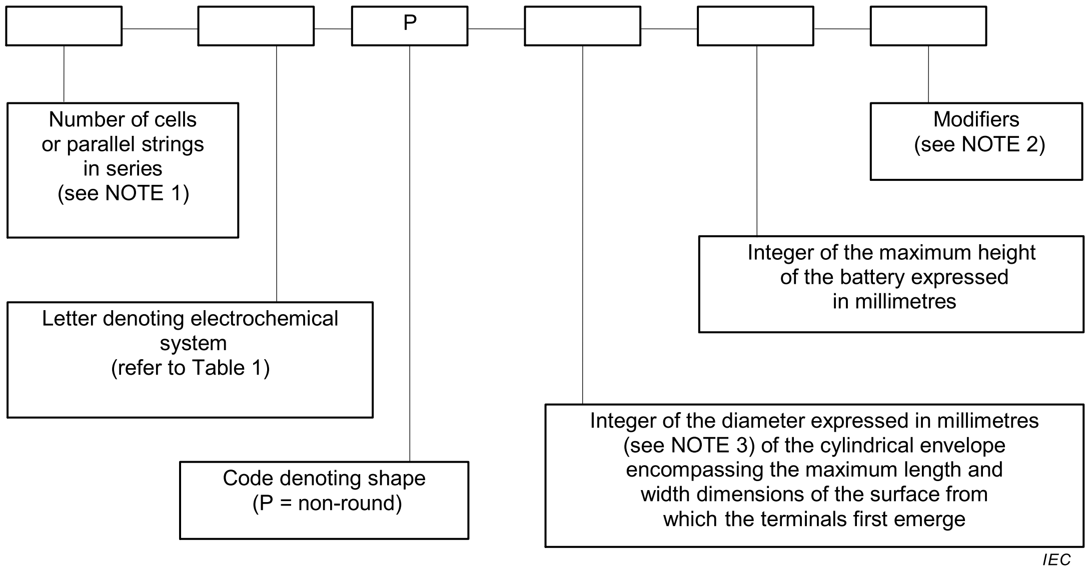
a) for flat contact terminals, the maximum height is the overall height including the terminals;

b) for all other types of terminals, the maximum height is the maximum overall height excluding the terminals (i.e. shoulder-to-shoulder).

NOTE In the event there are two or more terminals emerging from different surfaces, the one with the highest voltage applies.

C.3.3.2 Non-round batteries with dimensions < 100 mm

The designation for non-round batteries with dimensions < 100 mm is as shown in Figure C.5.



NOTE 1 The number of cells or strings in parallel is not identified.

NOTE 2 Modifiers are included to designate for example specific terminal arrangement, load and further special characteristics.

NOTE 3 In case the height needs to be discriminated in tenths of a millimetre, the letter code shown in Figure C.7 applies.

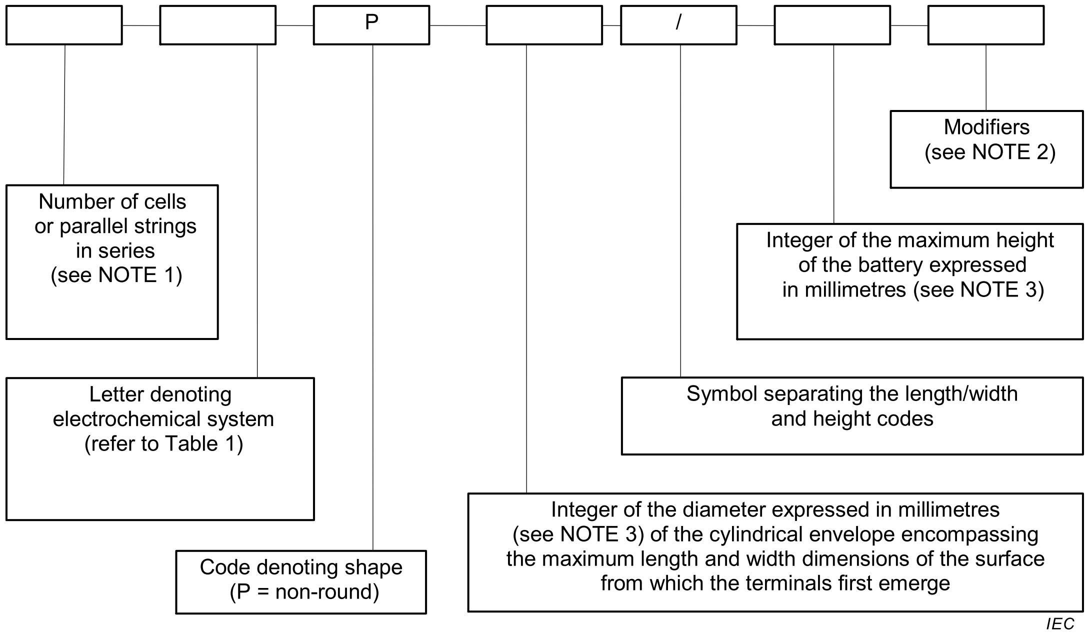
EXAMPLE 6LP3146: A battery consisting of six cells or strings in parallel of the zinc-alkali metal hydroxide-manganese dioxide system, connected in series with a maximum length of 26,5 mm, a maximum width of 17,5 mm, and a maximum height of 46,4 mm. The integer of the diameter of this surface (*l* and *w*) is calculated according to:

$$\sqrt{l^2 + w^2} = 31{,}8 \text{ mm; integer} = 31$$

Figure C.5 – Designation system for non-round batteries, dimensions < 100 mm

C.3.3.3 Non-round batteries with dimensions ≥ 100 mm

The designation for non-round batteries with dimensions ≥ 100 mm is as shown in Figure C.6.



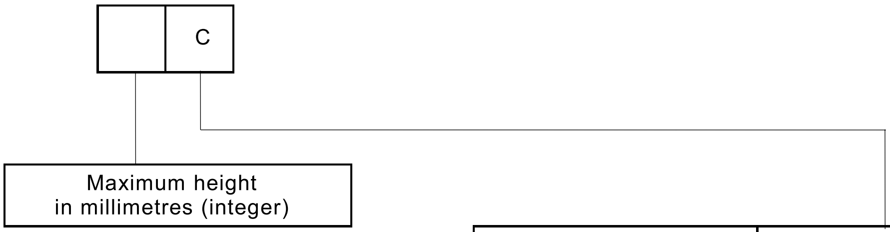
NOTE 1 The number of cells or strings in parallel is not identified.

NOTE 2 Modifiers are included to designate for example specific terminal arrangement, load and further special characteristics.

NOTE 3 In case the height needs to be discriminated in tenths of a millimetre, the letter code shown in Figure C.7 applies.

EXAMPLE 6P222/162: A battery consisting of six cells or strings in parallel of the zinc-ammonium chloride, zinc chloride-manganese dioxide system, connected in series, with a maximum length of 192 mm, a maximum width of 113 mm, and a maximum height of 162 mm.

Figure C.6 – Designation system for non-round batteries, dimensions ≥ 100 mm



Decimal part of height mm	Code
0,0	A
0,1	B
0,2	C
0,3	D
0,4	E
0,5	G
0,6	H
0,7	J
0,8	K
0,9	L

IEC

NOTE The tenths of a millimetre code is only used when needed.

Figure C.7 – Height code for discrimination per tenth of a millimetre

C.3.4 Ambiguity

In the unlikely event that two or more batteries would have the same diameter of the encompassing cylinder and the same height, the second one will be designated with the same designation extended with “–1”.

Table C.5 – Physical designation and dimensions of round cells and batteries based on Clause C.2

Dimensions in millimetres

Physical designation	Maximum battery dimensions	
	Diameter	Height
R772	7,9	7,2
R1025	10,0	2,5
R1216	12,5	1,6
R1220	12,5	2,0
R1225	12,5	2,5
R1616	16,0	1,6
R1620	16,0	2,0
R2012	20,0	1,2
R2016	20,0	1,6
R2020	20,0	2,0
R2025	20,0	2,5
R2032	20,0	3,2
R2320	23,0	2,0
R2325	23,0	2,5
R2330	23,0	3,0
R2354	23,0	5,4
R2420	24,5	2,0
R2425	24,5	2,5
R2430	24,5	3,0
R2450	24,5	5,0
R3032	30,0	3,2
R11108	11,6	10,8
2R13252	13,0	25,2
R12A604	12,0	60,4
R14250	14,5	25,0
R15H270	15,6	27,0
R17335	17,0	33,5
R17345	17,0	34,5
R17450	17,0	45,0
NOTE The complete dimensions of these batteries are given in IEC 60086-2 and IEC 60086-3.		

Table C.6 – Physical designation and dimensions of non-round batteries based on Clause C.2

Dimensions in millimetres

Physical designation	Designation (original)	Maximum battery dimensions		
		Length	Width	Height
2P3845	2R5	34,0	17,0	45,0
2P4036	R-P2	35,0	19,5	36,0
NOTE 1 The actual used designation of these batteries is 2R5 and R-P2 since these batteries were already recognized under these numbers before they were standardized. NOTE 2 The complete dimensions of these batteries are given in IEC 60086-2.				

Annex D
(informative)

Standard discharge voltage U_s – Definition and method of determination

D.1 Definition

The standard discharge voltage U_s is typical for a given electrochemical system. It is a unique voltage in that it is independent of both the size and the internal construction of the battery. It only depends on its charge-transfer reaction. The standard discharge voltage U_s is defined by Equation (D.1).

$$U_s = \frac{C_s}{t_s} \times R_s \qquad (D.1)$$

where

U_s is the standard discharge voltage;

C_s is the standard discharge capacity;

t_s is the standard discharge time;

R_s is the standard discharge resistor.

D.2 Determination

D.2.1 General considerations: the *C/R*-plot

The determination of the discharge voltage U_d is accomplished via a C/R-plot (where C is the discharge capacity of a battery; R is the discharge resistance). For illustration, see Figure D.1, which shows a schematic plot of discharge capacity C versus discharge resistor R_d [4] in normalized presentation, i.e. $C(R_d)/C_p$ is plotted as a function of R_d. For low R_d-values, low $C(R_d)$-values are obtained and vice versa. On the gradual increase of R_d, discharge capacity $C(R_d)$ also increases until finally a plateau is established and $C(R_d)$ becomes constant [5]:

$$C_p = \text{constant} \qquad (D.2)$$

which means $C(R_d)/C_p = 1$ as indicated by the horizontal line in Figure D.1. It further shows that capacity $C = f(R_d)$ is dependent on the cut-off voltage U_c: the higher its value, the larger is fraction ΔC that cannot be realised during discharge.

NOTE Under plateau conditions, capacity C is independent of R_d.

The discharge voltage U_d is determined by Equation (D.3).

$$U_d = \frac{C_d}{t_d} \times R_d \qquad (D.3)$$

[4] Subscript d differentiates this resistance from R_s; see Equation (D.1).

[5] For very long periods of discharge time C_p may decrease due to the battery's internal self-discharge. This may be noticeable for batteries having a high self-discharge, for example 10 % per month or above.

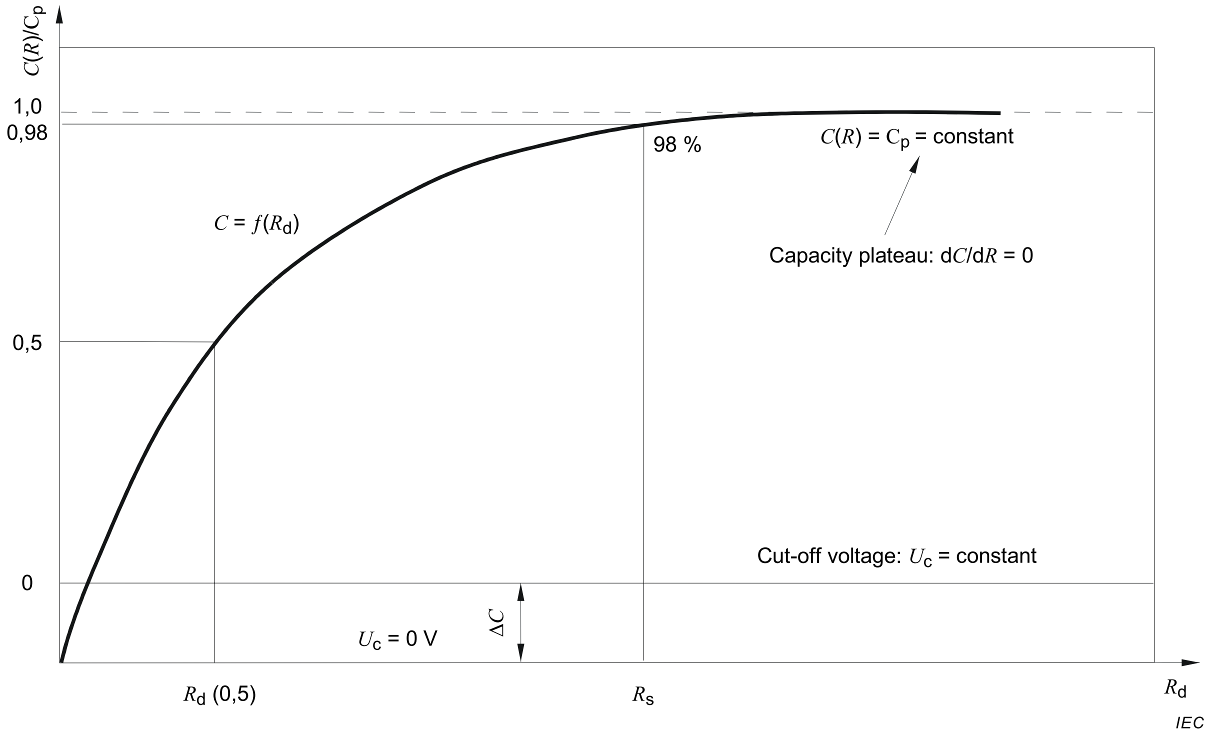


Figure D.1 – Normalized *C/R*-plot (schematic)

The quotient C_d / t_d of Equation (D.3) represents the average current i(avg) when discharging the battery through discharge resistor R_d for a given cut-off voltage U_c = constant. This relation may be written as:

$$C_d = i(\text{avg}) \times t_d \tag{D.4}$$

For $R_d = R_s$ (standard discharge resistor) Equation (D.3) changes to the Equation (D.1), and consequently Equation (D.4) changes to:

$$C_s = i(\text{avg}) \times t_s \tag{D.5}$$

The determination of i(avg) and t_s is accomplished according to the method described in D.2.3 and illustrated by Figure D.2.

D.2.2 Determination of the standard discharge resistor R_s

The determination of U_s is best achieved by that discharge resistor R_d, that yields 100 % capacity realization. The time to perform this discharge may be of long duration. To reduce this time, a good approximation for U_s is achieved by Equation (D.6).

$$C_s(R_s) = 0{,}98\ C_p \tag{D.6}$$

This means that 98 % capacity realization is considered to be of sufficient accuracy for the determination of the standard discharge voltage U_s. This is achieved when discharging the battery through the standard discharge resistor R_s. Its factor 0,98 or above is not decisive, because U_s remains practically constant for $R_s \leq R_d$. Under this condition, the exact realization of a 98 % capacity realization is not crucial.

D.2.3 Determination of the standard discharge capacity C_s and standard discharge time t_s

For illustration refer to Figure D.2, which represents a schematic discharge curve of a battery.

Figure D.2 addresses areas A1 below and A2 above the discharge curve. Under

$$A1 = A2 \tag{D.7}$$

the average discharge current i(avg) is obtained. The condition described by Equation (D.7) does not necessarily address the mid-point of discharge, as indicated in Figure D.2. The time of discharge t_d is determined from the cross-over point for $U(R,t) = U_c$. The discharge capacity is obtained from Equation (D.8).

$$C_d = i(\text{avg}) \times t_d \tag{D.8}$$

The standard capacity C_s is obtained for $R_d = R_s$, changing Equation (D.8) to Equation (D.9).

$$C_s = i(\text{avg}) \times t_s \tag{D.9}$$

a method which permits the experimental determination of the standard discharge capacity C_s and the standard discharge time t_s, needed for determination of the standard discharge voltage U_s (see Equation (D.1)).

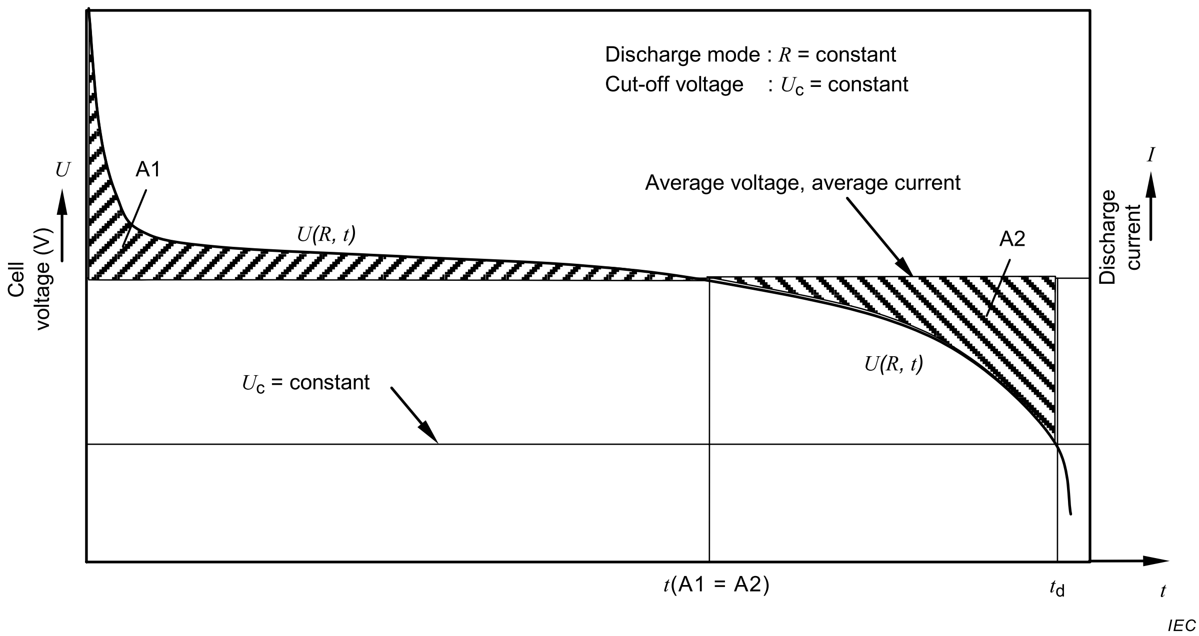


Figure D.2 – Standard discharge voltage (schematic)

D.3 Experimental conditions to be observed and test results

For the experimental determination of the C/R-plot, 10 individual discharge results are recommended, each one being the average of nine batteries; these data are to be evenly distributed over the expected range of the C/R-plot. It is recommended to take the first discharge value at approximately 0,5 C_p as indicated in Figure D.1. The last experimental value should be taken at approximately $R_d \approx 2 \times R_s$. The data gathered may then be graphically presented in the form of a C/R-plot according to Figure D.1. From this plot the R_d-

value is to be determined leading to approximately 98 % C_p. The standard discharge voltage U_s yielding a 98 % capacity realization should deviate by less than –50 mV from that value yielding a 100 % capacity realization. Differences within this mV range will only be caused by the charge-transfer reaction caused by the system under investigation.

When determining C_s and t_s according to D.2.3, the following cut-off voltages are to be employed in accordance with IEC 60086-2:

Voltage range 1: $U_c = 0,9$ V Voltage range 2: $U_c = 2,0$ V

The experimentally determined standard discharge voltages U_s (SDV) shown in Table D.1 are only given to permit the interested expert to check its reproducibility.

Table D.1 – Standard discharge voltage by system

System letter	No letter	C	E	F	L	S	W	Y	Z
U_s(SDV) V	1,30	2,90	3,50	1,48	1,30	1,55	2,8	3,5	1,56

The determination of U_s for systems A, B, G and P is under consideration. System P is a special case, because its U_s value depends on the type of catalyst for oxygen reduction. Since system P is an open system to air, the environmental humidity as well as the pick-up of CO_2 after the activation of the system, is of additional influence. For system P, U_s values of up to 1,37 V may be observed.

Annex E
(informative)

Preparation of standard methods of measuring performance (SMMP) of consumer goods

NOTE This annex has been derived from ISO/IEC Guide 36:1982, Preparation of standard methods of measuring performance (SMMP) of consumer goods (withdrawn 1998).

E.1 General

Information useful to consumers on the performance of consumer goods needs to be based on reproducible standard methods of measuring performance (i.e. test methods that lead to results having a clear relationship to the performance of a product in practical use and that are to be used as a basis for information to consumers about the performance characteristics of the product).

As far as possible, specified tests should take into account limitations in test equipment, money and time.

E.2 Performance characteristics

The first step in the preparation of a SMMP is to establish as complete a list as possible of the characteristics that are relevant in the sense discussed in Clause E.1.

NOTE Once such a list has been drawn up, consideration can be given to selecting those attributes of a product that are most important to consumers making purchase decisions.

E.3 Criteria for the development of test methods

A test method should be given for each of the performance characteristics listed. The following points should be taken into consideration:

a) the test methods should be defined in such a way that the test results correspond as closely as possible to the performance results as experienced by consumers when using the product in practice;
b) it is essential that the test methods are objective and give meaningful and reproducible results;
c) details of the test methods should be defined with a view to optimum usefulness to the consumer, taking into account the ratio between the value of the product and the expenses involved in performing the tests;
d) where use has to be made of accelerated test procedures, or of methods that have only an indirect relationship to the practical use of the product, the technical committee should provide the necessary guidance for correct interpretation of test results in relation to normal use of the product.

Annex F
(informative)

Calculation method for the specified value of minimum average duration

The calculation method for the specified value of minimum average duration shall be carried out as follows:

a) Prepare minimum 10 weeks' data of duration values which are randomly selected.

b) Calculate average $\bar{x}$ of duration values $\times$ of eight samples from each population.

Remark: If some values are out of 3 σ of that population, eliminate these values from the calculation of $\bar{x}$.

c) Calculate the average $\bar{\bar{x}}$ of the above average values $\bar{x}$ of each population and also $\sigma_{\bar{x}}$.

d) Minimum average duration value to be provided by each country:

$$\text{A: } \bar{\bar{x}} - 3\ \sigma_{\bar{x}}$$

$$\text{B: } \bar{\bar{x}} \times 0{,}85$$

Calculate both A and B; define the larger value of the above two as its minimum average duration.

Annex G
(normative)

Code of practice for packaging, shipment, storage, use and disposal of primary batteries

G.1 General

The greatest satisfaction to the user of primary batteries results from a combination of good practices during manufacture, distribution and use.

The purpose of this code is to describe these good practices in general terms. It takes the form of advice to battery manufacturers, distributors and users.

G.2 Packaging

The packaging shall be adequate to avoid mechanical damage during transport, handling and stacking. 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 moisture.

G.3 Transport and handling

Shock and vibration shall be kept to a minimum. For instance, boxes should not be thrown off trucks, slammed into position or piled so high as to overload battery containers below. Protection from inclement weather should be provided.

G.4 Storage and stock rotation

The storage area should be clean, cool, dry, ventilated and weatherproof.

For normal storage, the temperature should be between +10 °C and +25 °C and never exceed +30 °C. Extremes of humidity (over 95 % RH and below 40 % RH) for sustained periods should be avoided since they are detrimental to both batteries and packaging. Batteries should therefore not be stored next to radiators or boilers, nor in direct sunlight.

Although the storage life of batteries at room temperature is good, storage is improved at lower temperatures (e.g. in cold rooms –10 °C to +10 °C or in deep-freeze conditions below –10 °C), providing special precautions are taken. The batteries shall be enclosed in special protective packaging (such as sealed plastic bags or variants) which should be retained to protect them from condensation during the time they are warming to ambient temperature. Accelerated warming is detrimental.

Batteries which have been cold-stored should be put into use as soon as possible after return to ambient temperature.

Batteries may be stored, fitted in equipment or packages if determined suitable by the battery manufacturer.

The height to which batteries may be stacked is clearly dependent on the strength of the pack. As a general guide, this height should not exceed 1,5 m for cardboard packs or 3 m for wooden cases.

The above recommendations are equally valid for storage conditions during prolonged transit. Thus, batteries shall be stowed away from ship engines and not left for long periods in unventilated metal box cars (containers) during summer.

Batteries shall be dispatched promptly after manufacture and in rotation to distribution centres and on to the users. In order that stock rotation (first in, first out) can be practised, storage areas and displays shall be properly designed and packs adequately marked.

G.5 Displays at sales points

When batteries are unpacked, care should be taken to avoid physical damage and electrical contact. For example, they should not be jumbled together.

Batteries intended for sale should not be displayed for long periods in windows exposed to direct sunlight.

The battery manufacturer should provide sufficient information to enable the retailer to select the correct battery for the user's application. This is especially important when supplying the first batteries for newly purchased equipment.

Test meters do not provide reliable comparison of the service to be expected from good batteries of different grades and manufacture. They do, however, detect serious failures.

G.6 Selection, use and disposal

G.6.1 Purchase

The correct size and grade of battery most suitable for the intended use should be purchased. Many manufacturers supply more than one grade of battery in any given size. Information on the grade most suited to the application should be available at the sales point and on the equipment.

In the event that the required size and grade of battery of a particular brand is not available, the IEC designation for electrochemical system and size enables an alternative to be selected. This designation should be marked on the battery label. The battery should also clearly indicate the voltage, name or trade mark of the manufacturer or supplier, the date of manufacture, which may be in code, or the expiration of a guarantee period, in clear, as well as the polarity (+ and –). For some batteries, part of this information may be on the packaging (see 4.1.6.2).

G.6.2 Installation

Before inserting batteries into the battery compartment of the equipment, the contacts of both equipment and batteries should be checked for cleanliness and correct positioning. If necessary, clean with a damp cloth and dry before inserting.

It is of extreme importance that batteries are inserted correctly with regard to polarity (+ and –). Follow equipment instructions carefully and use the recommended batteries. Failure to follow the instructions, which should be available with the equipment, can result in malfunction and damage of the equipment and/or batteries.

G.6.3 Use

It is not good practice to use or leave equipment exposed to extreme conditions, for example radiators, or cars parked in the sun, etc.

It is advantageous to remove batteries immediately from equipment which has ceased to function satisfactorily, or when not in use for a long period (e.g. cameras, photoflash, etc.).

Be sure to switch off the equipment after use.

Store batteries in a cool, dry place and out of direct sunlight.

G.6.4 Replacement

Replace all batteries of a set at the same time. Newly purchased batteries should not be mixed with partially exhausted ones. Batteries of different electrochemical systems, grades or brands should not be mixed. Failure to observe these precautions may result in some batteries in a set being driven beyond their normal exhaustion point and thus increase the probability of leakage.

G.6.5 Disposal

Primary batteries may be disposed of via the communal refuse arrangements, provided no contrary local legal requirements exist. Refer to IEC 60086-4 and IEC 60086-5 for further details.

Bibliography

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

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

ISO/IEC Guide 36:1982, *Preparation of standard methods of measuring performance (SMMP) of consumer goods* (withdrawn 1998)

ISO 2859, *Sampling Procedures for Inspection by Attributes Package*

ISO 21747, *Statistical methods – Process performance and capability statistics for measured quality characteristics*

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