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IEC 60086-1

Tenth edition
2006-12

Primary batteries –

Part 1: General

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRIMARY BATTERIES –

Part 1: General

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60086-1 has been prepared by IEC technical committee 35: Primary cells and batteries.

This tenth edition cancels and replaces the ninth edition (2000) and constitutes a technical revision.

The major technical changes concern the addition of "Test condition tolerances" in 6.6 and the standardization of the "Z" electrochemical system (Nickel oxyhydroxide) included in Table 3.

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

FDIS	Report on voting
35/1244/FDIS	35/1247/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 the 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 maintenance result date indicated on the IEC web site 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- withdrawn;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. 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

The purpose of this part of IEC 60086 is to standardize primary batteries with respect to their electrochemical system, dimensions, nomenclature, terminal configurations, markings, test methods, typical performance, safety and environmental aspects.

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

The objective of IEC 60086-1 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60086-2, *Primary batteries – Part 2: Physical and electrical specifications*

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

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

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

IEC 60410, *Sampling plans and procedures for inspection by attributes*

IEC 61429, *Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135*

ISO/IEC Directives, Part 1: *Procedures for the technical work*

ISO 3951 (all parts as applicable), *Sampling procedures for inspection by variables*

3 Terms and definitions

For the purposes of this document, the definitions given in IEC 60050(482) (some of which are repeated below for convenience), as well as the following definitions, apply.

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

3.2
discharge (of a primary battery)
operation during which a battery delivers current to an external circuit

[IEV 482-03-23:2004, modified]

3.3
dry (primary) battery
primary battery in which the liquid electrolyte is immobilized

[IEV 482-04-14:2004, modified]

3.4
effective internal resistance – DC method
resistance of any electrical component determined by calculating the ratio between the voltage drop ΔU across this component and the range of current Δi passing through this component and causing the voltage drop $R = \Delta U / \Delta i$

NOTE As an analogy, the internal d.c. resistance of any electrochemical cell is defined by the following relation:

$$R_{\mathrm{i}}\ (\Omega) = \frac{\Delta U\ (\mathrm{V})}{\Delta i\ (\mathrm{A})} \quad (1)$$

The internal d.c. resistance is illustrated by the schematic voltage transient as given below:

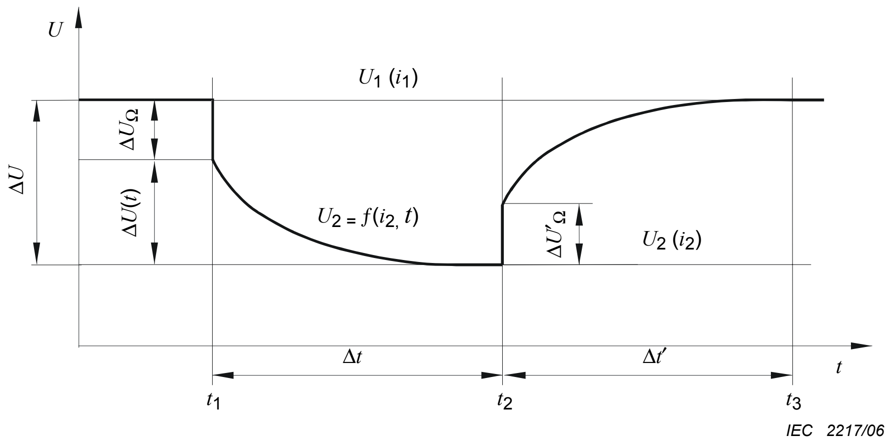

Figure 1 – Schematic voltage transient

As can be seen from this diagram, the voltage drop ΔU of the two components differs in nature, as shown in the following relation:

$$\Delta U = \Delta U_{\Omega} + \Delta U\ (t) \quad (2)$$

The first component ΔU_{Ω} for ($t = t_1$) is independent of time, and results from the increase in current Δi according to the relation:

$$\Delta U_{\Omega} = \Delta i \times R_{\Omega} \quad (3)$$

In this relation, R_{Ω} is a pure ohmic resistance. The second component $\Delta U(t)$ is time dependent and is of electrochemical origin.

3.5
end-point voltage
EV
specified voltage of a battery at which the battery discharge is terminated

[IEV 482-03-30:2004, modified]

3.6
leakage
unplanned escape of electrolyte, gas or other material from a battery

[IEV 482-02-32:2004, modified]

3.7
minimum average duration
MAD
minimum average time on discharge which shall be met by a sample of batteries

NOTE 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.

3.8
nominal voltage of a primary battery
$V_{\mathbf{n}}$
suitable approximate value of voltage used to identify the voltage of a primary battery

[IEV 482-03-31:2004, modified]

3.9
on-load voltage
closed-circuit voltage
CCV
voltage across the terminals of a battery when it is on discharge

[IEV 482-03-28:2004, modified]

3.10
open-circuit voltage
off-load voltage
OCV
voltage across the terminals of a battery when no current is flowing

[IEV 482-03-32:2004, modified]

3.11
primary battery
one or more primary cells, including case, terminals and marking

3.12
primary cell
source of electrical energy obtained by the direct conversion of chemical energy, that is not designed to be charged by any other electrical source

[IEV 482-01-02:2004, modified]

3.13
service output (of a primary battery)
service life, or capacity, or energy output of a battery under specified conditions of discharge

3.14
service output test
test designed to measure the service output of a battery

NOTE 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.

3.15
storage life
duration under specified conditions at the end of which a battery retains its ability to perform a specified service output

[IEV 482-03-47:2004, modified]

3.16
terminals (of a primary battery)
conductive parts provided for the connection of a battery to external conductors

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.

Additionally, 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

Terminals shall be in accordance with Clause 7 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 adequate electrical conductivity and corrosion protection.

4.1.3.1 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.

4.1.3.2 Cap and base

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

4.1.3.3 Cap and case

This type of terminal is used for batteries which have their dimensions specified according to Figures 3 and 4 of IEC 60086-2, but in which the cylindrical side of the battery forms part of the positive terminal.

4.1.3.4 Screw terminals

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

4.1.3.5 Flat contacts

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

4.1.3.6 Flat or spiral springs

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

4.1.3.7 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.

4.1.3.8 Snap fasteners

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.

4.1.3.8.1 Spacing of contacts

The spacing between the stud and socket is given in the following table and applies from centre to centre. The stud always forms the positive connection and the socket the negative connection on the battery.

Table 1 – Spacing of contacts

Nominal voltage V	Standard mm	Miniature mm
9	35 ± 0,4	12,7 ± 0,25

4.1.3.8.2 Non-resilient snap fastener connectors (studs)

All dimensions not specified are free. The shape of the studs shall be chosen so that they conform to the dimensions specified.

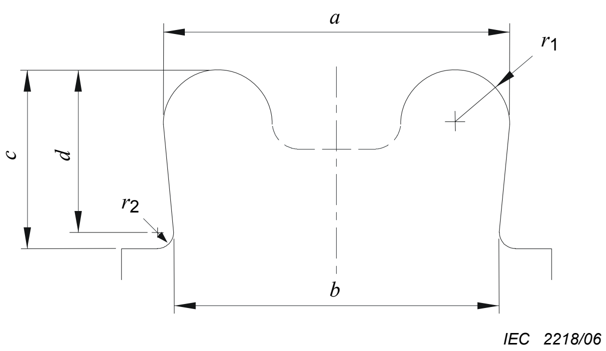

Figure 2 – Stud

Table 2 – Snap fastener connectors

	Standard mm	**Miniature** mm
a	7,16 ± 0,05	5,72 ± 0,05
b	$6{,}65^{+0{,}07}_{-0{,}05}$	5,38 ± 0,05
c	3,20 ± 0,1	3,00 ± 0,1
d	2,67 ± 0,05	2,54 ± 0,05
r_1	$0{,}61^{+0{,}05}_{-0{,}08}$	$0{,}9^{+0{,}1}_{-0{,}3}$
r_2	$0{,}4^{+0{,}3}_{0}$	$0{,}3^{+0{,}2}_{0}$

4.1.3.8.3 Resilient snap fastener connectors (sockets)

Dimensions and requirements:

The dimensions of the resilient (socket) parts of snap fastener connectors are not specified as such. The properties shall be such that

a) the resiliency ensures that the standardized studs can be properly mated,

b) good electrical contact is maintained.

4.1.3.9 Wire

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

4.1.3.10 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 3.

Table 3 – 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	1,725
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	1,65
P	Zinc (Zn)	Alkali metal hydroxide	Oxygen (O_2)	1,4	1,68
S	Zinc (Zn)	Alkali metal hydroxide	Silver oxide (Ag_2O)	1,55	1,63
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 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

With the exception of batteries designated as small, each battery shall be marked with the following information:

a) designation;

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 terminals (when applicable);

d) nominal voltage;

e) name or trade mark of the manufacturer or supplier;

f) cautionary advice.

4.1.6.2 Marking of small batteries

a) When this subclause is invoked in IEC 60086-2, mainly for category 3 and 4 batteries, 4.1.6.1a) and 4.1.6.1c) shall be marked on the battery. Subclauses 4.1.6.1b), 4.1.6.1d), 4.1.6.1e) and 4.1.6.1.f) may be given on the immediate package 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 of the battery and/or on the battery. Subclauses 4.1.6.1b), 4.1.6.1d) and 4.1.6.1e) may be given on the immediate package instead of on the battery.

c) Caution for ingestion of small batteries shall be given. Refer to IEC 60086-4 (subclauses 7.2 m) and 9.2) and IEC 60086-5 (subclauses 7.1 l) 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. Where required, refer to IEC 61429.

4.1.7 Interchangeability: battery voltage

Primary batteries as presently standardized in IEC 60086 can be categorized by their standard discharge voltage U_s[1]. For a new battery system, its interchangeability by voltage is assessed for compliance with the following formula:

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

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 F.

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 about 1,5 V, i.e. "no-letter" system, systems A, F, G, L, P, S and Z.

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[1] 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.

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

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 F 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 and IEC 60086-3.

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 4.1.4, Table 3.

4.2.5 Service output

Discharge durations, initial and delayed, of batteries shall meet the requirements given in IEC 60086-2 and IEC 60086-3.

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 G.

5.2 Discharge testing

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 methods of determining the load and test conditions are as follows:

5.2.1 Application tests

a) The equivalent resistance is calculated from the average current and average operating voltage of the equipment under load.
b) The functional end-point voltage and the equivalent resistance value are obtained from the data on all the equipment measured.
c) The median class defines the resistance 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.
e) In selecting the daily discharge period, the total weekly usage of the equipment is considered.

The daily period then becomes the nearest preferred value (see 6.5) to one-seventh of the total weekly usage.

NOTE 1 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 load conditions may become unavoidable. It is also inevitable 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 2 In order to minimize the proliferation of application tests, the tests specified should be those accounting for 80 % of the market by battery designation.

5.2.2 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, any of the application tests or service output tests specified in IEC 60086-2 and IEC 60086-3 may be chosen.

The test shall be carried out as follows:

a) Test nine 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 nine 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.

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

5.4 Calculation method of the specified value of minimum average duration

This method is described in Annex D.

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, visual examination for leakage shall be carried out in accordance with the applicable clause of IEC 60086-3.

6 Performance – Test conditions

6.1 Pre-discharge conditioning

Storage before discharge testing, and the actual discharge test, is carried out under well defined conditions. Unless otherwise specified, the conditions given in Table 4 shall apply. The discharge conditions shown are further referred to as standard conditions.

Table 4 – Conditions for storage before and during discharge testing

Type of test	Storage conditions			Discharge conditions	
	Temperature °C	Relative humidity[d] %	Duration	Temperature °C	Relative humidity[d] %
Initial discharge test	20 ± 2[a]	60 ± 15	60 days maximum after date of manufacture	20 ± 2	60 ± 15
Delayed discharge test	20 ± 2[a]	60 ± 15	12 months	20 ± 2	60 ± 15
Delayed discharge test (high temperature)[b]	45 ± 2[c]	50 ± 15	13 weeks	20 ± 2	60 ± 15

[a] During short periods only, the storage temperature may deviate from these limits without exceeding 20 °C ± 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 manufacturer and customer.

[c] Batteries to be stored unpacked.

[d] Except "P" system: (60 % ± 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 °C ± 2 °C and (60 % ± 15 %) RH (except for P-system batteries where the relative humidity shall be (60 % ± 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

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

When IEC 60086-2 specifies 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 5.

Table 5 – 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

together with their decimal multiples or sub-multiples.

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:

Table 6 – Time periods for new tests

1 min	5 min	10 min	30 min
1 h	2 h	4 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 7 shall apply.

Table 7 – Test condition tolerances

Test parameter	Tolerance	
Temperature	± 2 °C	
Load	± 0,5 %	
Voltage	± 0,5 %	
Relative humidity	± 15 % except "P" system ± 10 %	
Time "accuracy"	Discharge time t_d	Tolerance
	$0 < t_d \leq 2$ s	± 5 % of t_d
	2 s $< t_d \leq$ 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 manufacturer and purchaser.

Where no agreement is specified, the options in 7.1 and/or 7.2 are recommended.

7.1 Sampling

7.1.1 Testing by attributes

When testing by attributes is required, the sampling plan chosen shall be in accordance with the specifications of IEC 60410. The individual parameters to be tested and the acceptable quality level (AQL) values shall be defined (a minimum of three batteries of the same type shall be tested).

7.1.2 Testing by variables

When testing by variables is required, the sampling plan chosen shall be in accordance with ISO 3951. The individual parameters to be tested, the sample size and the acceptable quality level (AQL) shall be defined.

7.2 Product quality indices

Consideration may be given to utilizing one of the indices below as a means for assessing and ensuring product quality.

7.2.1 Capability index (c_p)

c_p is an index that represents the capability of a process. It explains how much of the tolerance range could be used up by the within sample process variation, σ', and is defined as c_p = (USL-LSL)/process width where process width is expressed as $6\overline{R}/d_2$. If the ratio is ≥1 and centred, the process is capable of making parts to specification. However, at c_p = 1, automatically 2 700 x 10^{-6} parts are outside of specifications.

NOTE USL = upper specification limit; LSL = lower specification limit; $\overline{R}$ = mean value of the range of the process; d_2 = common statistical coefficient related to $\overline{R}$.

7.2.2 Capability index (c_{pk})

c_{pk} is another process capability index that tells whether the process is capable of meeting tolerances and whether the process is centred around the target value.

Like c_p, it is assumed the samples come from a stable process and variation is random variation, measured as within sample variation, $\overline{R}/d_2$, from the control chart, where $\sigma' = \overline{R}/d_2$.

c_{pk} is the minimum of:

$$\frac{USL - \overline{X}}{3\sigma'} \text{ or } \frac{\overline{X} - LSL}{3\sigma'}$$

7.2.3 Performance index (p_p)

p_p is a process performance index that explains how much of the tolerance range is used up by the total variation in the system. It is a measure of how the system is actually performing because all sources of variation are included in σ'_T. This σ'_T is calculated by taking all the observations as one large sample. p_p is defined as $(USL - LSL)/6\sigma'_T$.

7.2.4 Performance index (p_{pk})

p_{pk} is another process performance index that is a measure of actual process performance as p_p above, but like c_{pk} it also tells how well the process is centred.

p_{pk} is the minimum of:

$$\frac{USL - \overline{X}}{3\,\sigma'_T} \text{ or } \frac{\overline{X} - LSL}{3\,\sigma'_T}$$

where σ'_T includes all sources of variation in the system.

8 Battery packaging

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

Annex A
(normative)

Guidelines for the standardization of batteries

Cells and batteries shall meet the following requirements to justify their initial inclusion or on-going retention in the IEC 60086 series:

a) The battery is in mass production.

b) The battery is available in several market places of the world.

c) The battery is produced currently 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.

Necessary items to include in any new work proposal to standardize a new individual battery:

1) Conformance statement to items a) to d) above.
2) Designation and electrochemical system.
3) Dimensions (including drawings).
4) Discharge conditions.
5) Minimum average duration(s).

Annex B
(normative)

Equipment design

B.1 Technical liaison

It is recommended that companies producing battery-powered equipment should 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

Battery compartments should be easily accessible. 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 publication 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.

Equipment intended for use by children should have battery compartments which are tamper-proof.

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 must 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 4 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 shall 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.3 Voltage cut-off

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

Annex C
(normative)

Designation system (nomenclature)

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.1 defines the designation system (nomenclature) in use up to October 1990.

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

C.1 Designation system in use up to October 1990

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.1.1 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[2], 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.1.2, C.1.3 and C.1.4. These tables only provide core physical designations for single cells or single batteries.

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[2] 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
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.1.2 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 3.

C.1.3 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.1.4 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 C, P or S to indicate different performance characteristics.

C.1.5 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.2 Designation system in use since October 1990

This clause applies to all batteries 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).

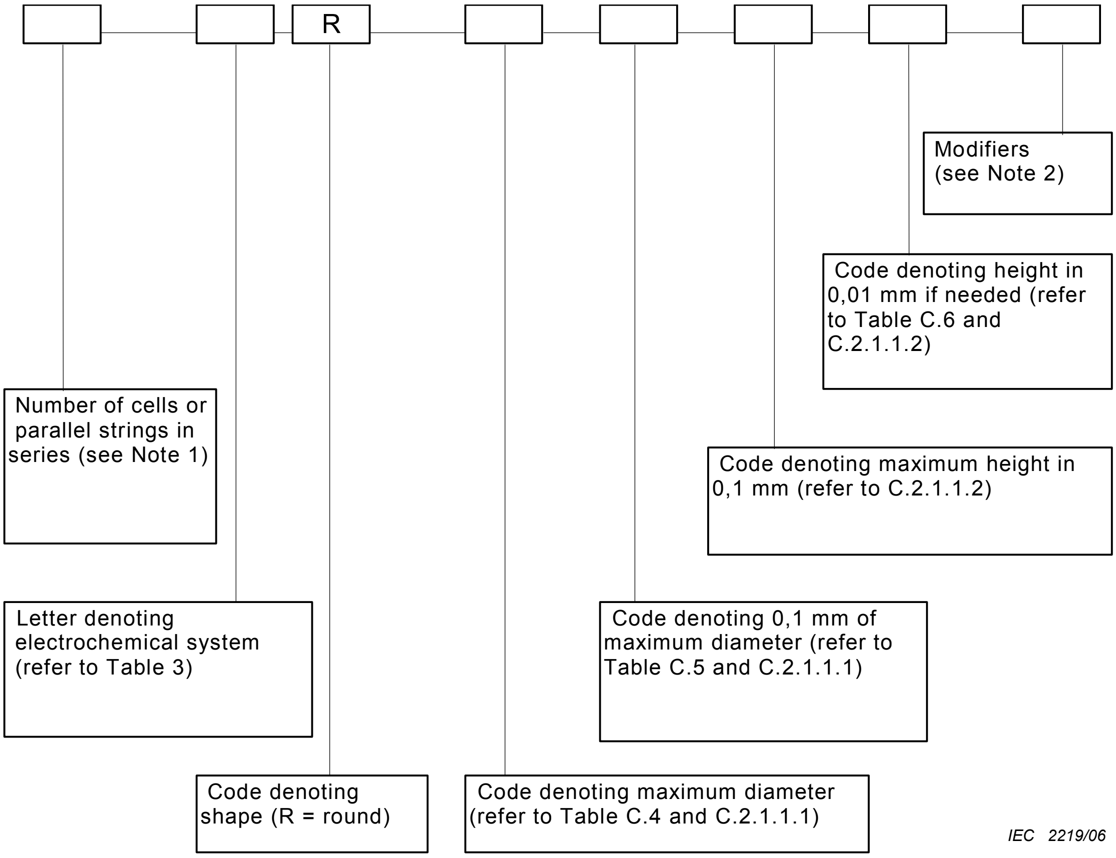
This clause also applies to single-cell batteries and multi-cell batteries with cells in series and/or parallel connection.

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.2.1 Round batteries

C.2.1.1 Round batteries with diameter and height less than 100 mm

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: Ø < 100 mm; height A < 100 mm

C.2.1.1.1 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,

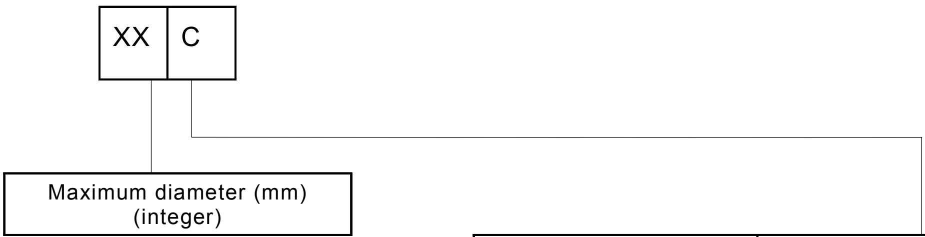
b) assigned according to Table C.5 in case of a non-recommended diameter.

Table C.4 – Diameter code for recommended diameters

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

Table C.5 – Diameter code for non-recommended diameters



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

C.2.1.1.2 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).

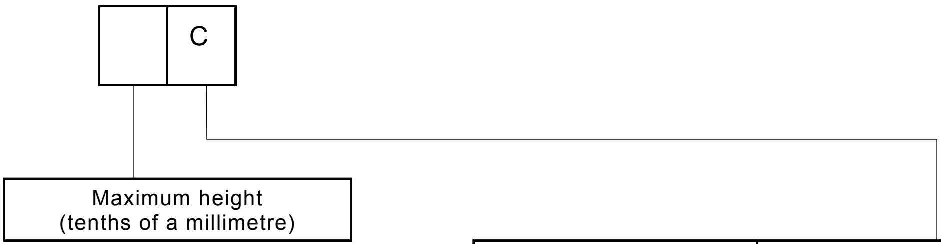
The maximum height is specified as follows:

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 Table C.6.

Table C.6 – Height code for denoting the hundredths of a millimetre of height



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

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

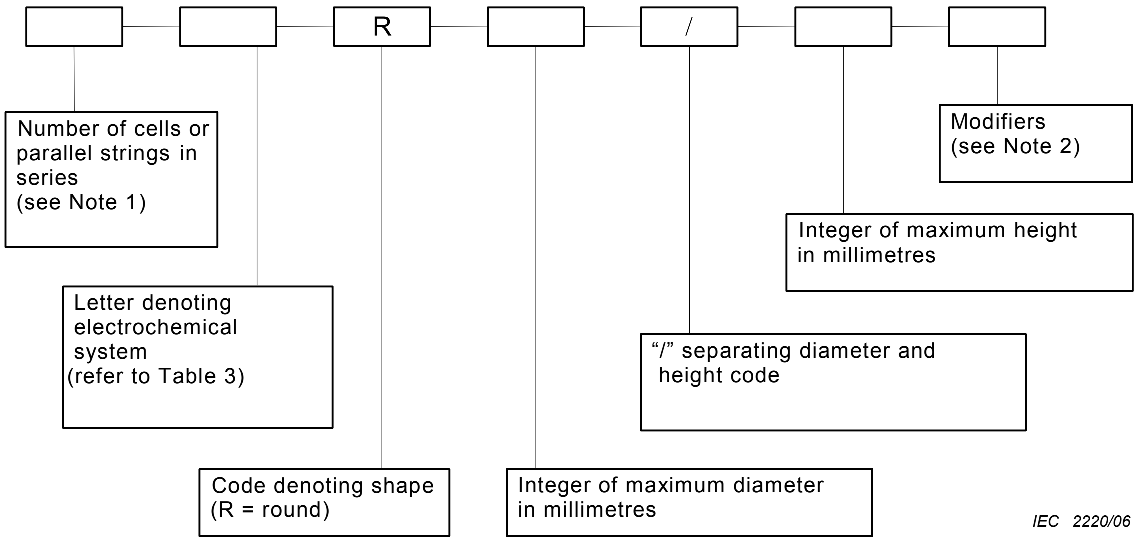
LR27A116: A battery consisting of a round cell or string in parallel with a maximum diameter of 27 mm (Table C.5) and a maximum height of 11,6 mm, of the zinc-alkali metal hydroxide-manganese dioxide system.

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 (Table C.6), of the zinc-alkali metal hydroxide-manganese dioxide system.

C.2.1.2 Round batteries with diameter and/or height over or equal to 100 mm

The designation for round batteries with a diameter and/or height ≥ 100 mm is as shown in Figure C.2.



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.2 – Designation system for round batteries: Ø ≥100 mm; height A ≥100 mm

C.2.1.2.1 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.2.1.2.2 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 to 4 in 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.2.2 Non-round batteries

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

C.2.2.1 Non-round batteries with dimensions <100 mm

The designation for non-round batteries with dimensions <100 mm is as shown in Figure C.3.

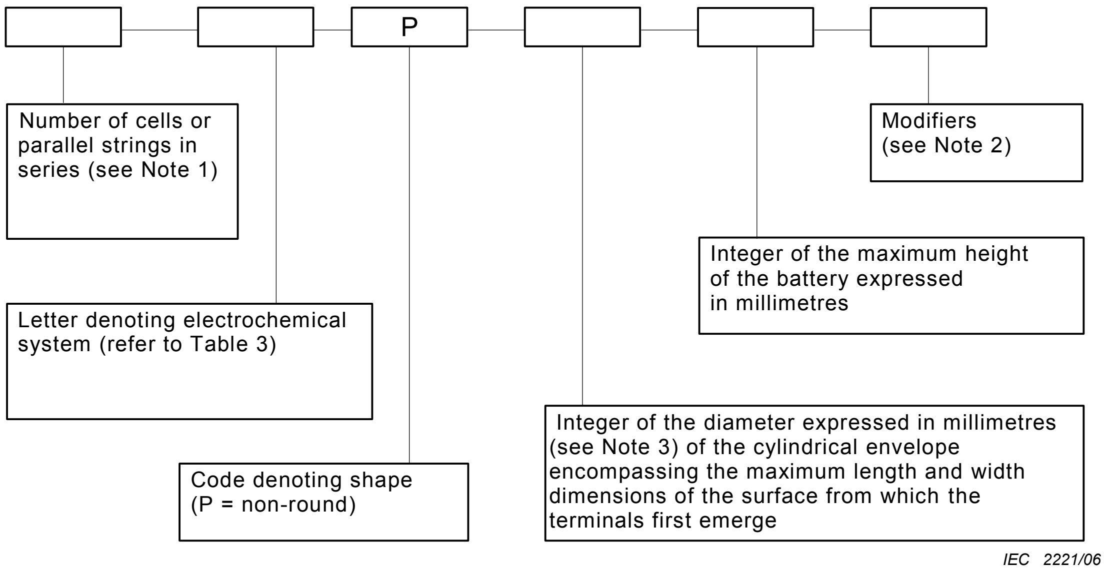


Figure C.3 – Designation system for non round batteries, dimensions <100 mm

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 Table 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:

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

C.2.2.2 Non-round batteries with dimensions ≥100 mm

The designation for non-round batteries with dimensions ≥100 mm is as shown in Figure C.4.

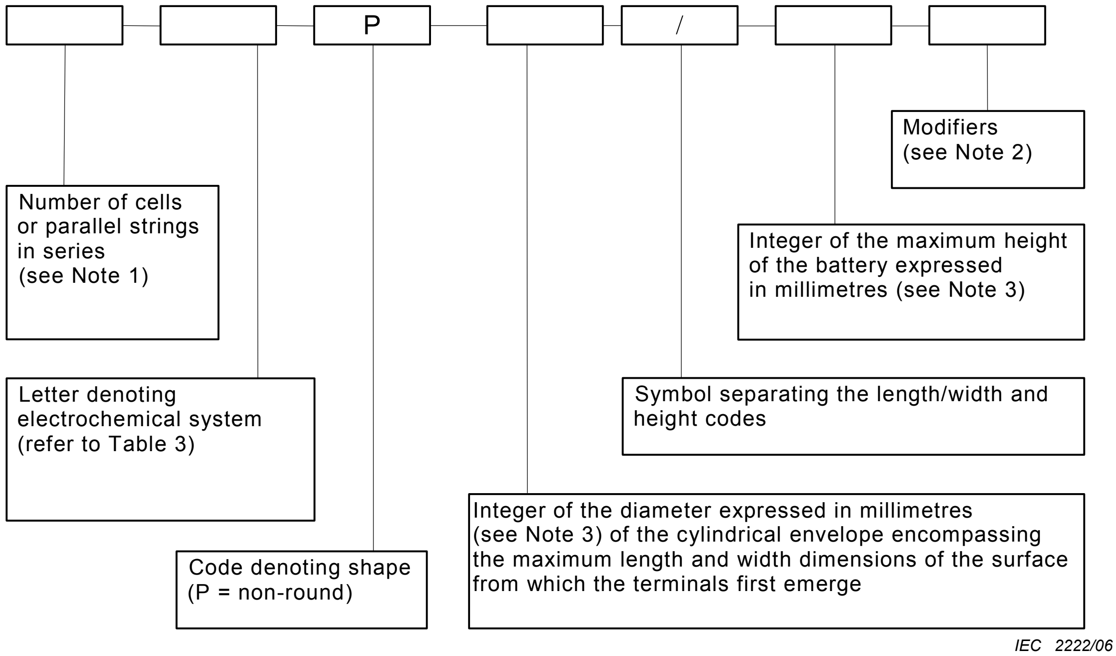


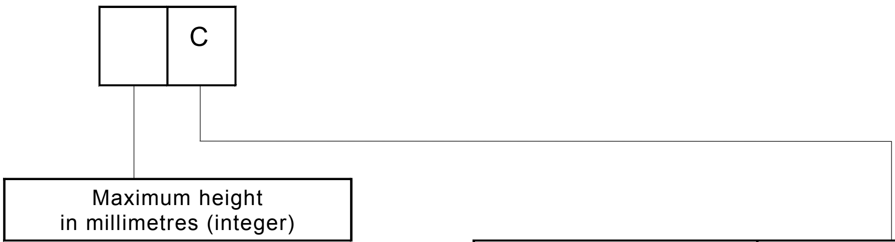
Figure C.4 – Designation system for non round batteries, dimensions ≥100 mm

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 Table C.7 applies.

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



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

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

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.

C.2.3 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.8 – 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.9 – 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
(normative)

Calculation method for the specified value of minimum average duration

The calculation method for specifying the value of the minimum average duration is as follows:

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

b) Calculate average $\bar{x}$ of duration values x of nine 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:

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

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

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

Annex E
(normative)

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

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.

E.1 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.

E.2 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.

E.3 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 % and below 40 % relative humidity) 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 ships' 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.

E.4 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.

E.5 Selection, use and disposal

E.5.1 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).

E.5.2 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.

E.5.3 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.

E.5.4 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.

E.5.5 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.

Annex F
(informative)

Standard discharge voltage U_s – Definition and method of determination

F.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 Formula (F.1).

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

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.

F.2 Determination

F.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 F.1, which shows a schematic plot of discharge capacity C versus discharge resistor R_d [3)] 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 [4)]:

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

which means $C(R_d)/C_P = 1$ as indicated by the horizontal line in Figure F.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 Formula (F.3).

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

3) Subscript d differentiates this resistance from R_s; see Formula (1).

4) 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.

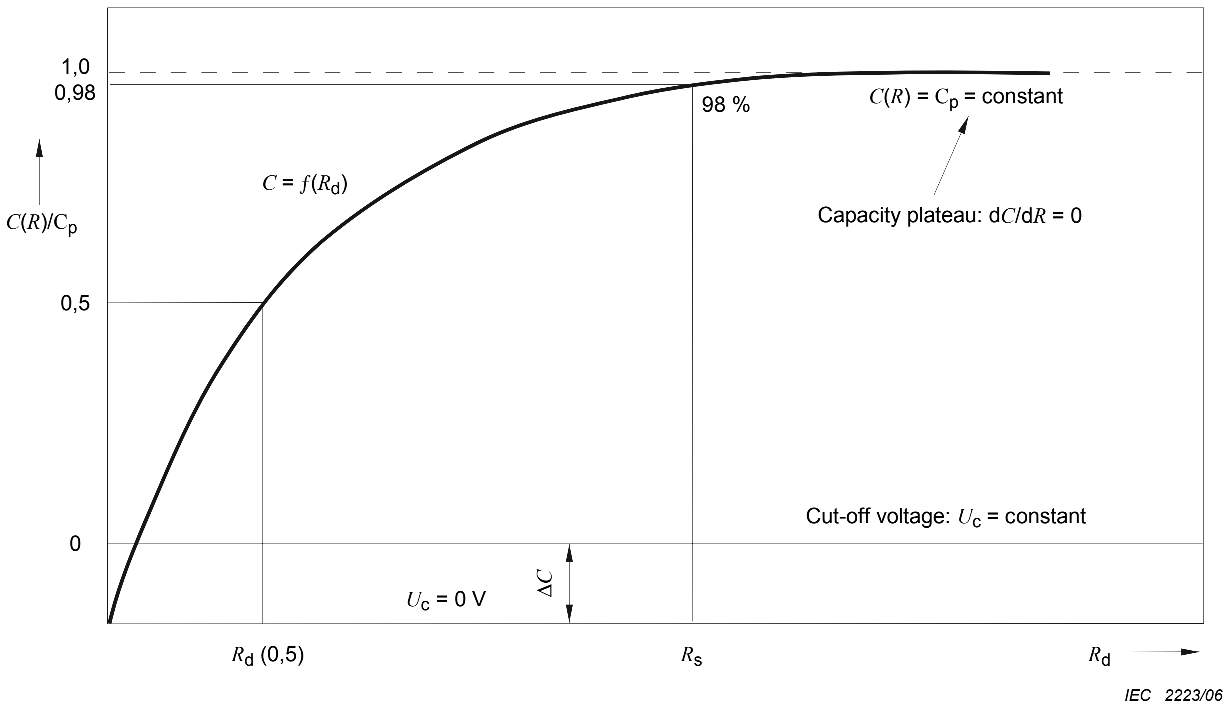


Figure F.1 – Normalized *C/R*-plot (schematic)

The quotient $C_d\ /t_d$ of Formula (F.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:

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

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

$$C_s = i(\text{avg}) \times t_s \tag{F.4a}$$

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

F.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 Formula (F.5).

$$C_s(R_s) = 0{,}98\ C_p \tag{F.5}$$

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.

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

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

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

$$A1 = A2 \quad \text{(F.6)}$$

the average discharge current i(avg) is obtained. The condition described by Formula (F.6) does not necessarily address the mid-point of discharge, as indicated in Figure F.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 Formula (F.7).

$$C_d = i(\text{avg}) \times t_d \quad \text{(F.7)}$$

The standard capacity C_s is obtained for $R_d = R_s$, changing Formula (F.7) to Formula (F.7a).

$$C_s = i(\text{avg}) \times t_s \quad \text{(F.7a)}$$

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 Formula (F.1)).

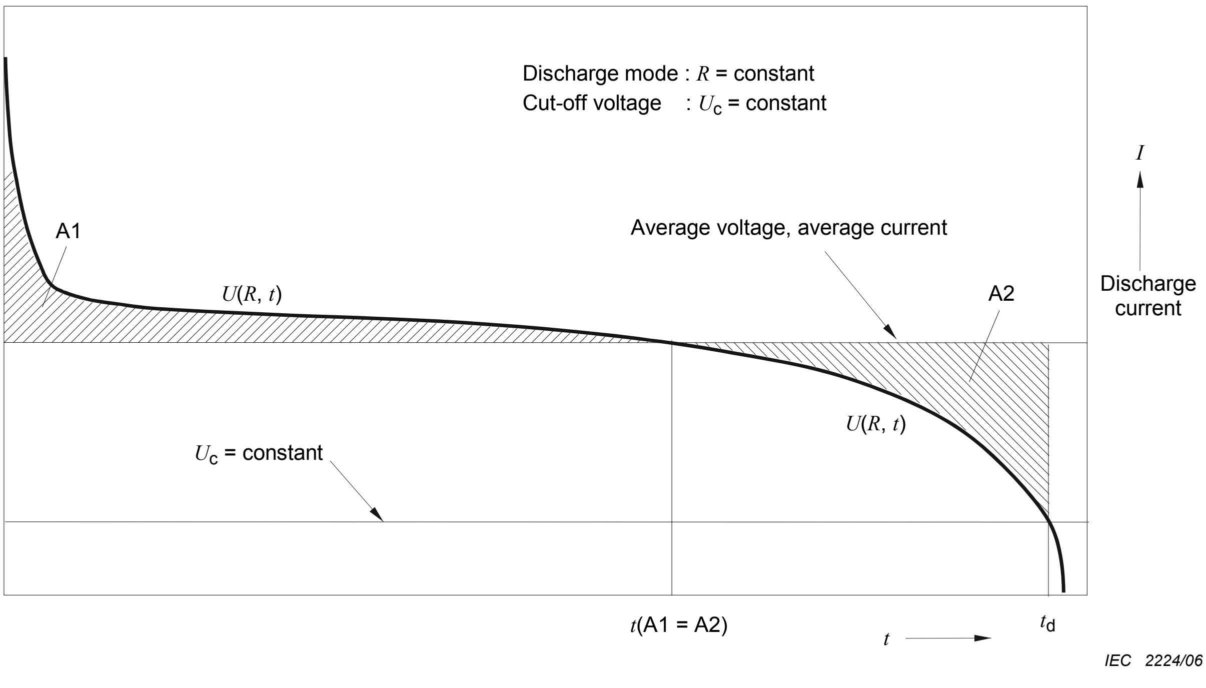


Figure F.2 – Standard discharge voltage (schematic)

F.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 $0,5C_P$ as indicated in Figure F.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 F.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 F.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 following experimentally determined standard discharge voltages U_s (SDV) are only given to permit the interested expert to check its reproducibility:

Table F.1 – Standard discharge voltage by system

System letter	No letter	C	E	F	L	S	Z
SDV: U_s(V)	1,30	2,90	3,50	1,48	1,30	1,55	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 G
(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).

G.1 Introduction

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

G.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 G.1.

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

G.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.

Bibliography

IEC 60050(482):2004, *International Electrotechnical Vocabulary (IEV) – Part 482: Primary and secondary cells and batteries*

ISO 7000: *Graphical symbols for use on equipment – Index and synopsis*

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- other...

Q3 I work for/in/as a: *(tick all that apply)*

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Q4 This standard will be used for: *(tick all that apply)*

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- product research ❑
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- specifications ❑
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- other...

Q5 This standard meets my needs: *(tick one)*

- not at all ❑
- nearly ❑
- fairly well ❑
- exactly ❑

Q6 If you ticked NOT AT ALL in Question 5 the reason is: *(tick all that apply)*

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- standard is incomplete ❑
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- title is misleading ❑
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