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INTERNATIONAL STANDARD

Primary batteries –
Part 3: Watch batteries

IEC 60086-3:2011(E)

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PRIMARY BATTERIES –

Part 3: Watch batteries

FOREWORD

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International Standard IEC 60086-3 has been prepared by IEC technical committee 35: Primary cells and batteries, and ISO technical committee 114: Horology.

This third edition cancels and replaces the second edition (2004) and constitutes a technical revision.

The major technical changes with respect to the previous edition are the drawings, a review of the table of electrochemical systems and a harmonization of the marking clause with the other standards of the IEC 60086 series. Moreover, the table of the leakage levels was extended by adding drawings with better visualization.

This publication is published as a double logo standard.

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

FDIS	Report on voting
35/1286/FDIS	35/1289/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. In ISO, the standard has been approved by 8 P members out of 8 having cast a vote.

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 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- withdrawn;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 specific requirements and information for primary watch batteries. This part was prepared through joint work between IEC TC 35 and ISO TC 114 to benefit primary battery users, watch designers and battery manufacturers by ensuring the best compatibility between batteries and watches.

This part will remain under continual scrutiny to ensure that the publication is kept up to date with the advances in both battery and watch technologies.

NOTE Safety information can be found in IEC 60086-4 and IEC 60086-5.

PRIMARY BATTERIES –

Part 3: Watch batteries

1 Scope

This part of IEC 60086 specifies dimensions, designation, methods of tests and requirements for primary batteries for watches. In several cases, a menu of test methods is given. When presenting battery electrical characteristics and/or performance data, the manufacturer specifies which test method was used.

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 60086-1:-[1], *Primary batteries – Part 1: General*

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

IEC 60086-4:2007, *Primary batteries – Part 4: Safety of lithium batteries*

IEC 60086-5:-[3], *Primary batteries – Part 5: Safety of batteries with aqueous electrolyte*

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

ISO 2859 (all parts), *Sampling procedures for inspection by attributes*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60086-1 as well as the following terms and definitions apply.

3.1
capacitive reactance
part of the internal resistance, that leads to a voltage drop during the first seconds under load

3.2
capacity
electric charge (quantity of electricity) which a cell or battery can deliver under specified discharge conditions

NOTE The SI unit for electric charge is the coulomb (1 C = 1 As) but, in practice, capacity is usually expressed in ampere hours (Ah).

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1 To be published in 2011.

2 To be published in 2011.

3 To be published in 2011.

3.3
fresh battery
undischarged battery 60 days maximum after date of manufacture

3.4
ohmic drop
part of the internal resistance that leads to a voltage drop immediately after switching the load on

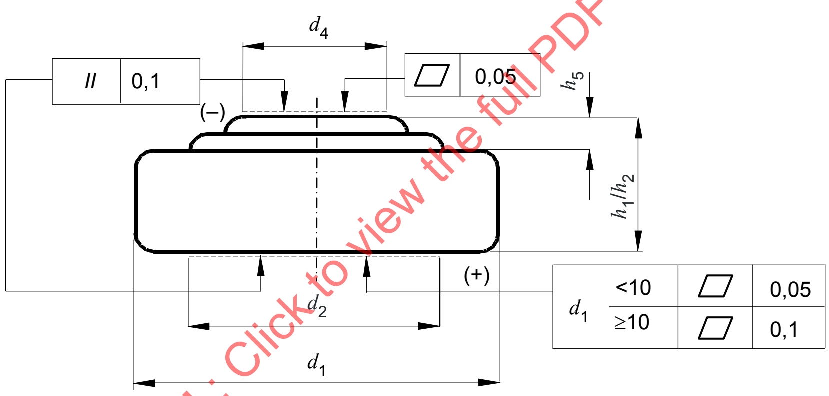
4 Physical requirements

4.1 Battery dimensions, symbols and size codes

Dimensions and tolerances of batteries for watches shall be in accordance with Figure 1, Table 1 and Table 2. The dimensions of the batteries shall be tested in accordance with 7.1.

The symbols used to denote the various dimensions in Figure 1 are in accordance with IEC 60086-2, Clause 4.

Dimensions in millimetres



IEC 155/11

Key

h_1	maximum overall height of the battery
h_2	minimum distance between the flats of the positive and negative contacts
h_5	minimum projection of the flat negative contact
d_1	maximum and minimum diameter of the battery
d_2	minimum diameter of the flat positive contact
d_4	minimum diameter of the flat negative contact

NOTE This numbering follows the harmonization in the IEC 60086 series.

Figure 1 – Dimensional drawing

Table 1 – Dimensions and size codes

Dimensions in millimetres

Diameter			d_4	Height h_1/h_2														
				Code [a]														
Code[a]	d_1	Tole-rance		10	12	14	16	20	21	25	26	27	30	31	32	36	42	54
				Tolerance														
				0 −0,10	0 −0,15	0 −0,15	0 −0,18	0 −0,20	0 −0,20	0 −0,20	0 −0,20	0 −0,20	0 −0,25	0 −0,25	0 −0,25	0 −0,25	0 −0,25	0 −0,25
4	4,8	0 −0,15					1,65		2,15									
5	5,8	0 −0,15	2,6	1,05	1,25	1,45	1,65		2,15			2,70						
6	6,8	0 −0,15	3,0	1,05	1,25	1,45	1,65		2,15		2,60							
7	7,9	0 −0,15	3,5	1,05	1,25	1,45	1,65		2,10		2,60			3,10		3,60		5,40
9	9,5	0 −0,15	4,5	1,05	1,25	1,45	1,65	2,05				2,70				3,60		
11	11,6	0 −0,20	6,0	1,05	1,25	1,45	1,65	2,05			2,60		3,05			3,60	4,20	5,40
12	12,5	0 −0,25	4,0		1,20		1,60	2,00		2,50								

NOTE Open boxes in the above matrix are not necessarily available for standardisation due to the concept of overlapping tolerances.

[a] See Annex A.

Table 2 – Dimensions and size codes

Dimensions in millimetres

Diameter			d_4	Height h_1/h_2					
				Code [a]					
Code [a]	d_1	Tolerance		12	16	20	25	30	32
				Tolerances					
				0 −0,20 [b]	0 −0,20 [b]	0 −0,25 [b]	0 −0,30 [b]	0 −0,30 [b]	0 −0,30 [b]
16	16	0 −0,25	5,00	1,20	1,60	2,00	2,50		3,20
20	20	0 −0,25	8,00	1,20	1,60	2,00	2,50		3,20
23	23	0 −0,30	8,00	1,20	1,60	2,00	2,50		
24	24,5	0 −0,30	8,00	1,20	1,60			3,00	

NOTE Open boxes in the above matrix are not necessarily available for standardisation due to the concept of overlapping tolerances.

[a] See Annex A.

[b] To be reduced in the future.

4.2 Terminals

Negative contact (–): the negative contact (dimension d_4) shall be in accordance with Tables 1 and 2. This is not applied to those batteries with a two-step negative contact.

Positive contact (+): the cylindrical surface is connected to the positive terminal. Positive contact should be made to the side of the battery but may be made to the base.

4.3 Projection of the negative terminal (h_5)

The dimension h_5 shall be as follows:

$h_5 \geq 0{,}02$ for $h_1/h_2 \leq 1{,}65$

$h_5 \geq 0{,}06$ for $1{,}65 < h_1/h_2 < 2{,}5$

$h_5 \geq 0{,}08$ for $h_1/h_2 \geq 2{,}5$

NOTE The negative contact should be the highest point of the battery.

4.4 Shape of negative terminal

The space requirements shall be contained within an angle of 45° (see Figure 2).

The minimum values of l_1, for different heights of h_1/h_2, are given in Table 3.

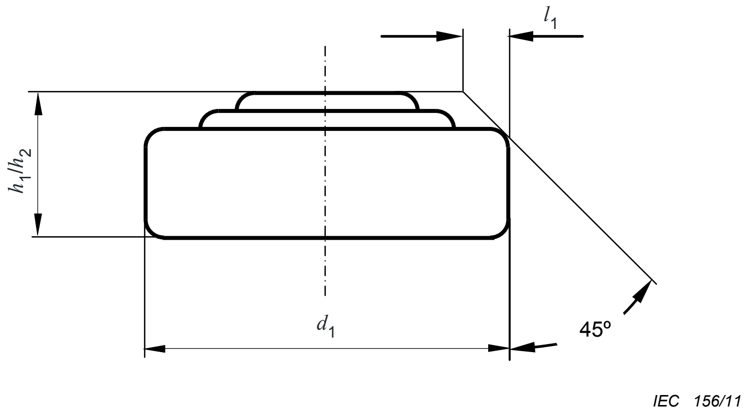


Figure 2 – Shape of negative terminal

Table 3 – Minimum values of l_1

Dimensions in millimetres

h_1/h_2	$l_{1\ min}$
$1 < h_1/h_2 \leq 1{,}90$	0,20
$1{,}90 < h_1/h_2 \leq 3{,}10$	0,35
$3{,}60 \leq h_1/h_2 \leq 4{,}20$	0,70
$5{,}40 \leq h_1/h_2$	0,90

4.5 Mechanical resistance to pressure

A force *F* (N), as specified in Table 4, applied for 10 s through a steel ball of 1 mm diameter, at the centre of each contact area, shall not cause any deformation prejudicial to the proper functioning of the battery, i.e. after this test, the battery shall pass the tests specified in Clause 7.

Table 4 – Applied force *F* by battery dimensions

Battery dimensions		Force
d_1 mm	h_1/h_2 mm	*F* N
<7,9	<3,0	5
	≥3,0	10
≥7,9	<3,0	10
	≥3,0	10

4.6 Deformation

The dimensions of batteries shall conform with the relevant specified dimensions at all times including discharge to the defined end-point voltage.

NOTE 1 A battery height increase up to 0,25 mm can occur in B, C, L and S systems, if discharged below this voltage.

NOTE 2 A battery height decrease can occur in B and C systems as discharge continues.

4.7 Leakage

Undischarged batteries and, if required, batteries tested according to 7.2.6 shall be examined as stated in 7.3. The acceptable number of defects shall be agreed between the manufacturer and the purchaser.

4.8 Marking

4.8.1 General

The designation and the polarity shall be marked on the battery. All other markings may be given on the packing instead of on the battery:

a) designation according to normative Annex A, 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. The code is composed by the last digit of the year and by a number indicating the month. October, November and December should be represented by the letters O, Y and Z respectively.

   EXAMPLE

   41: January 2014;

   4Y: November 2014.

c) polarity of the positive (+) terminal;

d) nominal voltage;

e) name or trade mark of the supplier;

f) cautionary advice;

g) caution for ingestion of swallowable batteries shall be given. Refer to IEC 60086-4:2007 (7.2 m) and 9.2) and IEC 60086-5:- (7.1 l) and 9.2) for details.

NOTE 1 Battery marking should not impede electrical contact.

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

4.8.2 Disposal

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

5 Electrical requirements

5.1 Electrochemical system, nominal voltage, end-point voltage and open-circuit voltage

The requirements concerning the electrochemical system, the nominal voltage, the end-point voltage and the open-circuit voltage are given in Table 5.

Table 5 – Standardised electrochemical systems

Letter	Negative electrode	Electrolyte	Positive electrode	Nominal voltage (V_n) V	End-point voltage (EV) V	Open-circuit voltage (U_{OC} or OCV) V	
						Max.	Min.
B	Lithium (Li)	Organic electrolyte	Carbon monofluoride $(CF)_x$	3,0	2,0	3,70	3,00
C	Lithium (Li)	Organic electrolyte	Manganese dioxide (MnO_2)	3,0	2,0	3,70	3,00
L	Zinc (Zn)	Alkali metal hydroxide	Manganese dioxide (MnO_2)	1,5	1,0	1,68	1,50
S	Zinc (Zn)	Alkali metal hydroxide	Silver oxide (Ag_2O)	1,55	1,2	1,63	1,57

5.2 Closed circuit voltage U_{cc} (CCV), internal resistance and impedance

Closed circuit voltage and internal resistance shall be measured according to 7.2.

AC impedance should be measured with an LCR meter.

Limit values shall be agreed between the manufacturer and the purchaser.

5.3 Capacity

The capacity shall be agreed between the manufacturer and the purchaser on the basis of a continuous discharge test lasting approximately 30 days, according to 7.2.6.

5.4 Capacity retention

The capacity retention is the ratio between the capacities under the given discharge conditions measured on fresh batteries and a sample of the same lot stored during 365 days at (20 ± 2) °C and a relative humidity between 45 % and 75 %.

The ratio of capacity retention shall be agreed between the manufacturer and the purchaser. The minimum value should be at least 90 % for a period of 12 months. The capacity measurement is carried out according to 7.2.6.

6 Sampling and quality assurance

6.1 General

The use of sampling plans or product quality indices may be agreed between manufacturer and purchaser. Where no agreement is specified, the options in 6.2 and/or 6.3 are recommended.

6.2 Sampling

6.2.1 Testing by attributes

When testing by attributes is required, the sampling plan chosen shall be in accordance with the specifications of IEC 60410 and/or ISO 2859. The individual parameters to be tested and the acceptance quality level (AQL) values shall be defined (a minimum of three batteries of the same type shall be tested).

6.2.2 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 and the acceptance quality level (AQL) shall be defined.

6.3 Product quality indices

Consideration may be given to utilising one of the indices shown in IEC 60086-1.

7 Test methods

7.1 Shape and dimensions

7.1.1 Shape requirement

The shape of the negative contact is checked preferably by optical projection or by an open gauge according to Figure 3.

The measurement method shall be agreed between the manufacturer and the purchaser.

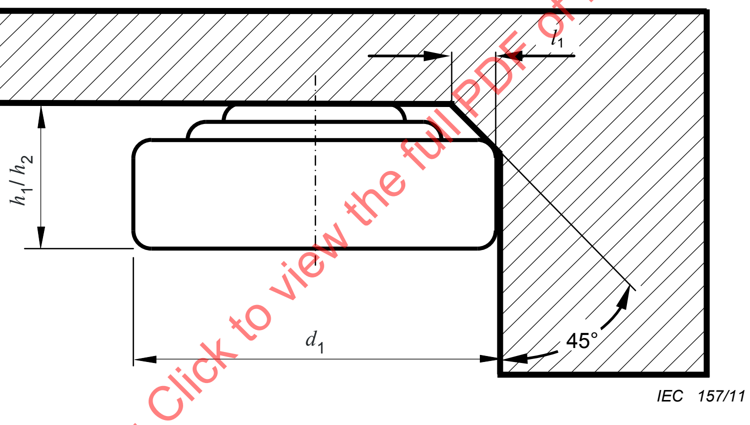


Figure 3 – Shape requirement

7.2 Electrical characteristics

7.2.1 Environmental conditions

Unless otherwise specified, the sample batteries shall be tested at a temperature of (20 ± 2) °C and a relative humidity between 45 % and 75 %.

During use, batteries may be exposed to low temperatures; it is therefore recommended to carry out complementary tests at (0 ± 2) °C and at (–10 ± 2) °C.

7.2.2 Equivalent circuit – 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 R_i of any electrochemical cell is defined by the following relation:

$$R_i\,(\Omega) = \frac{\Delta U\,(\mathrm{V})}{\Delta i\,(\mathrm{A})} \qquad (1)$$

The internal d.c. resistance is illustrated by the schematic voltage transient as given below in Figure 4.

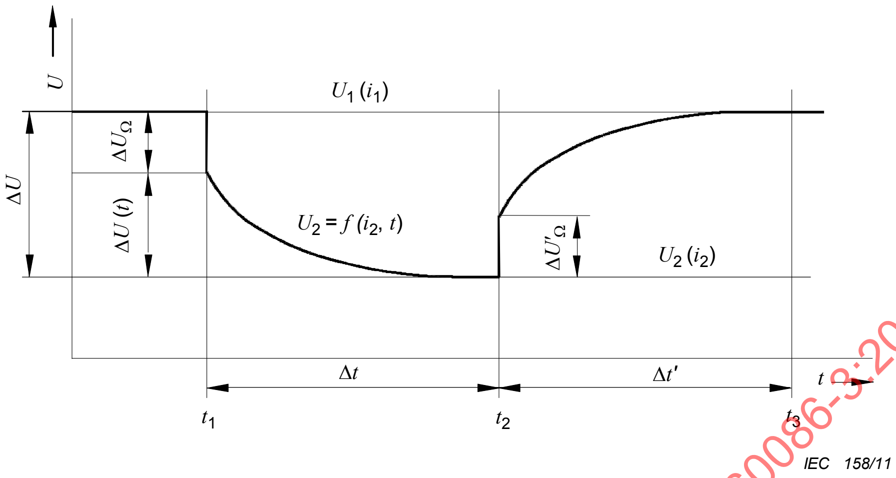


Figure 4 – Schematic voltage transient

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

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

The first component ΔU_Ω for (t = t_1) is independent of time (ohmic drop), and results from the increase in current Δi according to the relation:

$$\Delta U_\Omega = \Delta i \times R_\Omega \tag{3}$$

In this relation, R_Ω is a pure ohmic resistance. The second component $\Delta U\ (t)$ is time dependent and is of electrochemical origin (capacitive reactance).

7.2.3 Equipment

The equipment used for the voltage measurements shall have the following specifications :

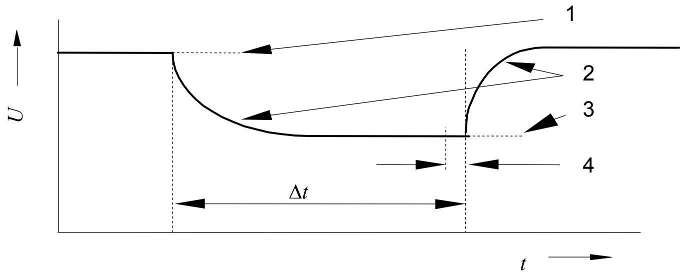
– accuracy: ≤0,25 %;

– precision: ≤50 % of last digit;

– internal resistance: ≥1 MΩ;

– measurement time: in the tests proposed in the following subclauses, it is important to make sure that the measurement is taken during the flat period of the voltage transient (see Figure 5). Otherwise, a measurement error due to the capacitive reactance may occur (lower internal resistance).

The time $\Delta t'$ necessary for the measurement shall be brief in comparison to Δt, and the measurement equipment compatible with these criteria.



Key

1 open-circuit voltage U_{oc} (OCV)

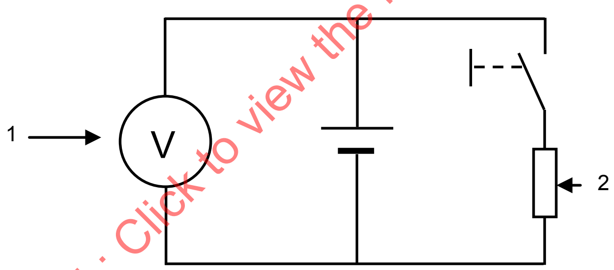
2 effect of capacitive reactance

3 closed circuit voltage U_{cc} (CCV)

4 $\Delta t'$ (measurement U_{cc})

Figure 5 – Curve: $U = f(t)$

7.2.4 Measurement of open-circuit voltage U_{oc} (OCV) and closed circuit voltage U_{cc} (CCV) (see Figure 6)



Key

1 reading U_{cc} / U_{oc}

2 R_m resistance of measurement

Figure 6 – Circuitry principle

First measurement	U_{oc}: The switch is left open while this measurement is being carried out.
Next measurement	U_{cc}: The battery being tested shall be connected to the load R_m. The switch shall be left closed during the duration Δt according to Table 6.

Table 6 – Test method for U_{cc} (CCV) measurement

Test method	Battery with KOH electrolyte [a]		All other batteries	
	R_m Ω	Δt s	R_m Ω	Δt ms
A [b]	150 ± 0,5 %	1 ± 5 %	1 500 ± 0,5 %	10 ± 5 %
B [c]	150 ± 0,5 %	0,5 – 2	470 ± 0,5 %	500 – 2 000
C [d]	200 ± 0,5 %	5 ± 5 %	2 000 ± 0,5 %	7,8 ± 5 %

NOTE R_m should take into consideration the resistance of the connection lines of the battery being tested and the contact resistance of the switch.

[a] Application with high peak current.

[b] Method A (recommended test): requires specialised test equipment.

[c] Method B: to be used in the absence of method A test equipment.

[d] Method C: to be used only by agreement between the manufacturer and the purchaser.

7.2.5 Calculation of the internal resistance R_i

The internal resistance may be determined by the following calculation:

$$R_i = \frac{U_{oc} - U_{cc}}{U_{cc} / R_m}$$

NOTE The relation U_{cc} / R_m corresponds to the current delivered through the discharge resistance R_m (see 7.2.4).

7.2.6 Measurement of the capacity

7.2.6.1 General

There are two methods for measuring capacity:

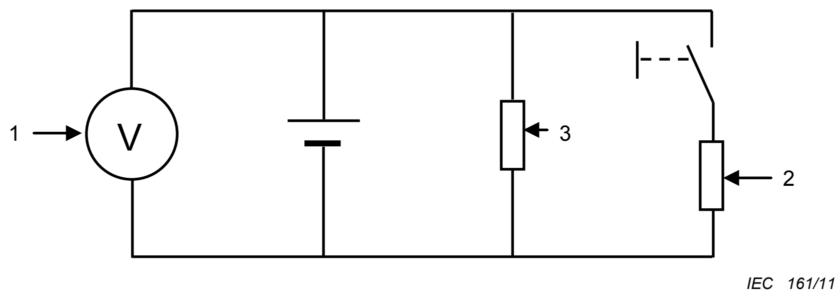
– the recommended method is method A, which is more indicative of watch requirements;

– method B is a more general method and is already specified in IEC 60086-1 and IEC 60086-2.

When presenting capacity data, the manufacturer shall specify which test method was used.

7.2.6.2 Method A

a) Circuitry principle (see Figure 7)



Key

1 reading U_{cc} / U'_{oc}

2 R_m resistance of measurement

3 R_d resistance of continuous discharge

Figure 7 – Circuitry principle for method A

b) Procedure

The duration of the discharge test at the resistor R_d approximates to 30 days.

Value of the resistance R_d: the value of the resistive load (specified in Table 8) shall include all parts of the external circuit and shall be accurate to within ± 0,5 %.

c) Determination of the capacity

The measurements of the open-circuit voltage U'_{oc} and that of the closed circuit voltage U_{cc} are carried out at least once a day on the battery permanently connected to R_d, until the first passage of the U_{cc} under the end-point voltage defined in Table 5 is obtained.

1) First measurement U'_{oc}: the resistance R_d being much higher than R_m, U'_{oc} approximates to U_{oc}.

The switch is left open while the measurement is being carried out.

2) Next measurement U_{cc}: the battery being tested is connected to R_m. The switch is left closed during the duration Δt according to Table 7.

Table 7 – Test method A for U_{cc} (CCV) measurement

Batteries with KOH electrolyte		All other batteries	
R_m Ω	Δt s	R_m Ω	Δt ms
150 ± 0,5 %	1 ± 5 %	1 500 ± 0,5 %	10 ± 5 %

NOTE 1 The value of resistive loads (which includes all parts of the external circuit) should be as specified in Table 7 and Table 8.

3) Calculation of the capacity C: the capacity of the battery is obtained by adding the partial capacity amounts C_p, calculated after each measurement with the following formula:

$$C_p = \frac{U'_{oc} \times t_i}{R_d}$$

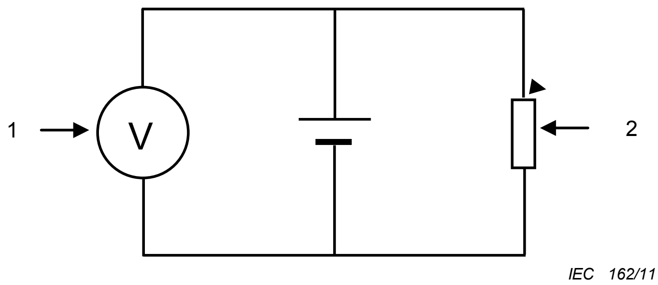
where t_i is the time between two measurements

$$C = \Sigma\, C_p$$

NOTE 2 At the end of the discharge, it is recommended to carry out several measurements a day in order to obtain sufficient accuracy.

7.2.6.3 Method B

a) Circuitry principle (see Figure 8)



Key

1 reading U_{cc}

2 R_d resistance of continuous discharge

Figure 8 – Circuitry principle for method B

b) See procedure in 7.2.6.2 b).

c) Determination of the capacity: when the on-load voltage of the battery under test drops for the first time below the specified end point as specified in Table 5, the time *t* is calculated and defined as service life.

The capacity is calculated by the following formula:

$$C = \frac{U_{cc}\,(\text{average})}{R_d} t$$

where

C	is the capacity;
U_{cc}(average)	is the average voltage value of U_{cc} during discharge duration time (0-t);
t	is the service life.

7.2.7 Calculation of the internal resistance R_i during discharge in case of method A (optional)

After each measurement of U'_{oc} and U_{cc} is carried out according to the procedure described in 7.2.6, it is possible to calculate the internal resistance R_i of the battery using the following formula:

$$R_i = \frac{U'_{oc} - U_{cc}}{U_{cc} / R_m}$$

Table 8 – Discharge resistance (values)

Code number according to the dimensions	Letter for electrochemical systems		Code number according to the dimensions	Letter for electrochemical systems	
	L	S		C	B
	Discharge resistance kΩ			Discharge resistance kΩ	
416			1212		
421			1216		
510			1220	62	
512			1225		
514			1612		
516		150	1616		
521		100	1620	47	
527		68	1625		
610			1632		
612			2012		
614		120	2016	30	
616		100	2020	30	
621		68	2025	15	
626		47	2032		
710			2312		
712		100	2316		
714		68	2320	15	
716		68	2325		
721		47	2412		
726		33	2416		
731		27	2430		
736		22			
754		15			
910					
912					
914					
916		47			
920		33			
927		22			
936		15			
1110					
1112					
1114					
1116		39			
1120		22			
1126		15			
1130		15			
1136		15			
1142		10			
1154		6,8			
NOTE Blank values under consideration.					

7.3 Test methods for determining the resistance to leakage

7.3.1 Preconditioning and previous examination

Before carrying out the tests specified in 7.3.2 and 7.3.3, the batteries shall be submitted to a visual examination according to the requirements stated in Clause 8.

For tests in 7.3.2.1 and 7.3.2.2, batteries shall be preconditioned at the specified temperature (40 °C and 45 °C respectively) for 2 h to avoid condensation at elevated humidity.

7.3.2 High temperature and humidity test

7.3.2.1 Recommended test

The battery shall be stored under the conditions specified in Table 9.

Table 9 – Storage conditions for the recommended test

Temperature °C	**Relative humidity** %	**Test time** day
40 ± 2	90 to 95	30 or 90
NOTE The test time of 30 days may be used for an accelerated routine quality control test, whereas the test time of 90 days applies to qualification testing of new batteries.		

7.3.2.2 Optional test

After agreement between the manufacturer and purchaser, the following testing conditions may be chosen (see Table 10).

Table 10 – Storage conditions for optional test

Temperature °C	**Relative humidity** %	**Test time** day
45 ± 2	90 to 95	20 or 60
NOTE The test time of 20 days may be used for an accelerated routine quality control test, whereas the test time of 60 days applies to qualification testing of new batteries.		

7.3.3 Test by temperature cycles

The battery shall be submitted to 150 temperature cycles according to the schedule in Figure 9:

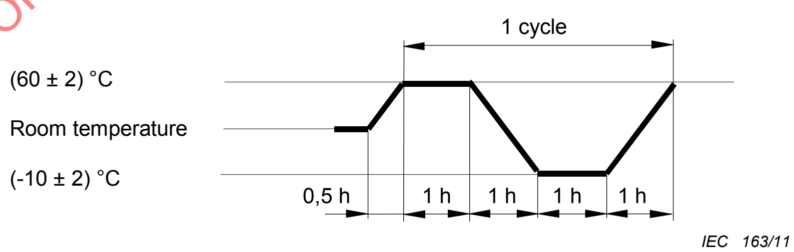


Figure 9 – Test by temperature cycles

The relative humidity shall be 50 % to 60 % at room temperature; it will subsequently vary with the temperature variation.

8 Visual examination and acceptance conditions

8.1 Preconditioning

Before carrying out the previous visual examination or after the tests specified in Clause 7, the batteries shall be stored for at least 24 h at room temperature and at a relative humidity between 45 % and 70 %.

NOTE 1 The leakage should, as a rule, be observed after crystallisation of the electrolyte. The time of the storage of 24 h can be prolonged if necessary.

NOTE 2 This examination may be applied to new or used batteries, or to batteries which have been submitted to different tests.

8.2 Magnification

The visual examination shall be carried out at a magnification of x10 to x15. The magnification of x15 is necessary in order to detect small leaks.

8.3 Lighting

The visual examination shall be carried out under a diffuse white light of 900 lx to 1 100 lx at the surface of the battery to be inspected.

8.4 Leakage levels and classification

The leakage levels and classification are given in Table 11.