INTERNATIONAL STANDARD

IEC 60086-1

1996

AMENDMENT 2
1999-03

Amendment 2

Primary batteries –

Part 1: General

Amendement 2

Piles électriques –

Partie 1: Généralités

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FOREWORD

This amendment has been prepared by IEC technical committee 35: Primary cells and batteries.

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

FDIS	Report on voting
35/1090/FDIS	35/1097/RVD

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

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

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7.5 Off-load voltage limits

Add, after this subclause, the following new subclause 7.6:

7.6 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:

$$n \times (U_r - 15\ \%) \leq m \times U_s \leq n \times (U_r + 15\ \%)$$

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 C.

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.

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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 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 and S.

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 physically non-interchangeable. Before standardizing a new electrochemical system, its standard discharge voltage shall be determined in accordance with the procedure given in annex C 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.

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Add, after annex B, the new annex C as follows:

Annex C
(informative)

Standard discharge voltage – definition and method of determination

C.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 the formula in (1):

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

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.

C.2 Determination

C.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 the battery; *R* is the discharge resistance). For illustration, see figure 1, which shows a schematic plot of discharge capacity *C* versus discharge resistor R_d [1)] 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 [2)]:

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

which means $C(R_d)/C_p = 1$ as indicated by the horizontal line in figure C.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 realized during discharge.

NOTE – Under plateau conditions capacity *C* is independent of R_d.

The discharge voltage U_d is determined by formula (3).

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

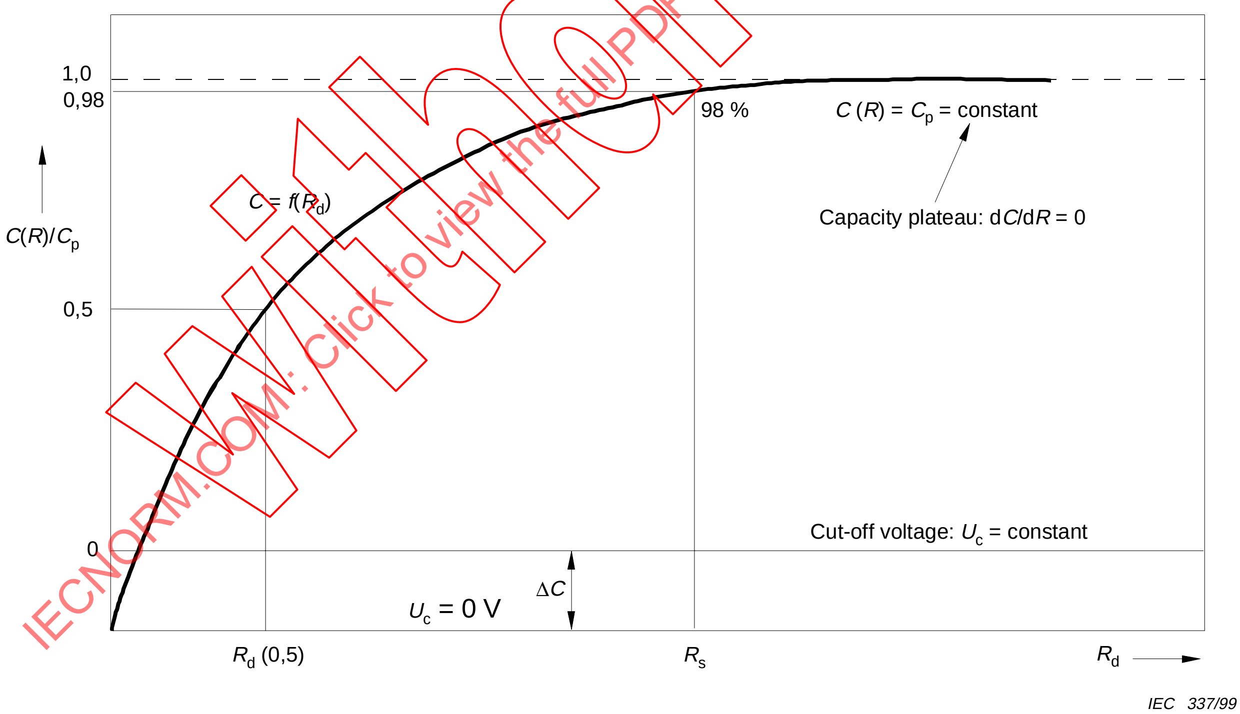

Figure C.1 – Normalized *C/R*-plot (schematic)

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

2) 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.

The quotient C_d/t_d of formula (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

$$C_d = i(\text{avg}) \times t_d \quad (4)$$

For $R_d = R_s$ (standard discharge resistor) the formula given in (3) changes to the formula given in (1), and consequently (4) changes to

$$C_s = i(\text{avg}) \times t_s \quad (4a)$$

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

C.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 the formula given in (5).

$$C_s(R_s) = 0{,}98\ C_p \quad (5)$$

which means that a 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.

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

For illustration refer to figure C.2, which represents a schematic discharge curve of a battery.

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

$$A1 = A2 \quad (6)$$

the average discharge current i(avg) is obtained. Condition (6) does not necessarily address the midpoint of discharge, as indicated in figure C.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 (7).

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

The standard discharge capacity C_s is obtained for $R_d = R_s$, changing formula (7) to formula (7a)

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

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 (1)).

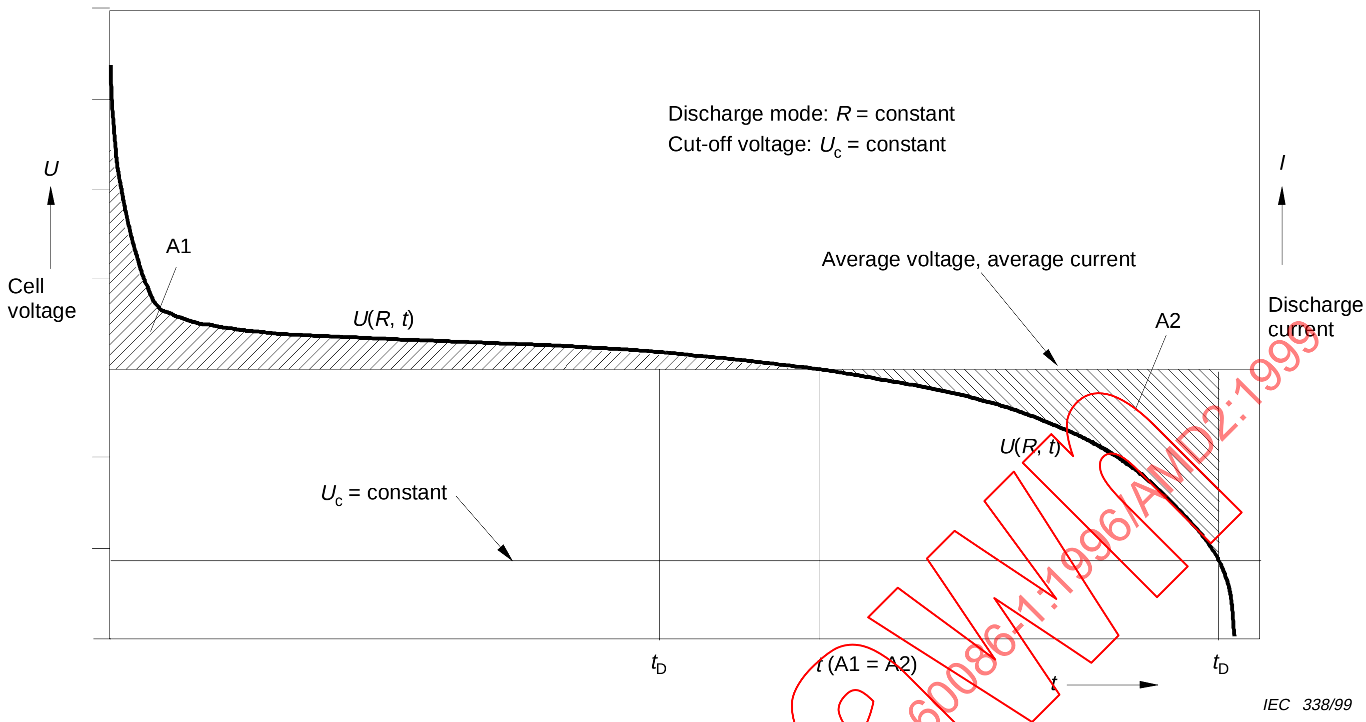

Figure C.2 – Discharge curve (schematic)

C.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, this data to be evenly distributed over the expected range of the *C/R*-plot. It is recommended to take the first discharge value at approximately 0,5 C_p as indicated in figure C.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 C.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 C.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:

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

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.