

INTERNATIONAL STANDARD



Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing



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IEC 62660-1

Edition 2.0 2018-12
REDLINE VERSION

INTERNATIONAL STANDARD



Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.220.20; 43.120

ISBN 978-2-8322-6349-5

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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THE PROPULSION OF ELECTRIC ROAD VEHICLES –****Part 1: Performance testing****FOREWORD**

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International Standard IEC 62660-1 has been prepared by IEC technical committee 21: Secondary cells and batteries.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) The purpose of each test has been added.
- b) The power test has been revised for clarification, and an informative part of the current-voltage characteristic test has been moved to the new Annex C.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
21/975/FDIS	21/985/RVD

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

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

A list of all the parts in the IEC 62660 series, published under the general title *Secondary lithium-ion cells for the propulsion of electric road vehicles*, can be found on the IEC website.

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

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- withdrawn,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

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INTRODUCTION

The commercialization of electric road vehicles including battery, hybrid and plug-in hybrid electric vehicles has been accelerated in the global market, responding to the global concerns on CO₂ reduction and energy security. This, in turn, has led to rapidly increasing demand for high-power and high-energy-density traction batteries. Lithium-ion batteries are estimated to be one of the most promising secondary batteries for the propulsion of electric vehicles. In the light of ~~rapidly-diffusing~~ the rapid spread of hybrid electric vehicles and the emergence of battery and plug-in hybrid electric vehicles, a standard method for testing performance requirements of lithium-ion batteries is indispensable for securing a basic level of performance and obtaining essential data for the design of vehicle systems and battery packs.

This document specifies performance testing for automobile traction lithium-ion cells that basically differ from the other cells including those for portable and stationary applications specified by other IEC standards. For automobile application, it is important to note the usage specificity; i.e. the design diversity of automobile battery packs and systems, and specific requirements for cells and batteries corresponding to each of such designs. Based on these facts, the purpose of this document is to provide a basic test methodology with general versatility, which serves a function in common primary testing of lithium-ion cells to be used in a variety of battery systems.

This document is associated with ~~ISO 12405-1 and ISO 12405-2~~¹ ISO 12405-4 [1]².

IEC 62660-2 [2] specifies the reliability and abuse testing for lithium-ion cells for electric vehicle application.

IEC 62660-3 [3] specifies the safety requirements of lithium-ion cells for electric vehicle application.

¹ ~~Under consideration.~~

² Numbers in square brackets refer to the Bibliography.

SECONDARY LITHIUM-ION CELLS FOR THE PROPULSION OF ELECTRIC ROAD VEHICLES –

Part 1: Performance testing

1 Scope

This part of IEC 62660 specifies performance and life testing of secondary lithium-ion cells used for propulsion of electric vehicles including battery electric vehicles (BEV) and hybrid electric vehicles (HEV).

NOTE 1 Secondary lithium-ion cell used for propulsion of plug-in hybrid electric vehicle (PHEV) can be tested by the procedure either for BEV application or HEV application, according to the battery system design, based on the agreement between the cell manufacturer and the customer.

This document specifies the test procedures to obtain the essential characteristics of lithium-ion cells for vehicle propulsion applications regarding capacity, power density, energy density, storage life and cycle life.

This document provides the standard test procedures and conditions for testing basic performance characteristics of lithium-ion cells for vehicle propulsion applications, which are indispensable for securing a basic level of performance and obtaining essential data on cells for various designs of battery systems and battery packs.

NOTE 2 Based on the agreement between the cell manufacturer and the customer, specific test conditions ~~may~~ can be selected in addition to the conditions specified in this document. Selective test conditions are described in Annex A.

NOTE 3 The performance tests for the electrically connected lithium-ion cells ~~may~~ can be performed with reference to this document.

NOTE 4 The test specification for lithium-ion battery packs and systems is defined in ~~ISO 12405-1 and ISO 12405-2 (under consideration)~~ ISO 12405-4 [1].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-482, International Electrotechnical Vocabulary – Part 482: Primary and secondary cells and batteries~~

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

ISO/TR 8713, *Electrically propelled road vehicles – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ~~IEC 60050-482~~ ISO/TR 8713 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

battery electric vehicle

BEV

electric vehicle with only a traction battery as power source for vehicle propulsion

3.2

hybrid electric vehicle

HEV

vehicle with both a rechargeable energy storage system and a fuelled power source for propulsion

3.3

rated capacity

C_n

~~quantity of electricity C_n Ah (ampere-hours) for BEV and C_1 Ah for HEV declared by the manufacturer~~

capacity value of a cell in ampere hours (Ah) determined under specified conditions and declared by the cell manufacturer

Note 1 to entry: n in C_n is the time base in hours (h). In this document, $n = 3$ for BEV application and $n = 1$ for HEV application unless otherwise specified.

3.4

~~reference test current~~

I_t

~~current in amperes which is expressed as~~

$$~~I_t (A) = C_n (Ah) / 1 (h)~~$$

~~where~~

~~C_n is the rated capacity of the cell;~~

reference test current in amperes (A) which is expressed as

$$I_t = C_n / 1$$

Note 1 to entry: 1 has a dimension of time in hours (h).

Note 2 to entry: See IEC 61434:1996 [4], Clause 2.

3.5

room temperature

temperature of $25\text{ °C} \pm 2\text{ K}$

3.6

secondary lithium-ion cell

cell

secondary single cell whose electrical energy is derived from the insertion and extraction reactions of lithium ions between the anode and the cathode

Note 1 to entry: The secondary lithium-ion cell is a basic manufactured unit providing a source of electrical energy by direct conversion of chemical energy. It consists of electrodes, separators, electrolyte, container and terminals, and is designed to be charged electrically.

NOTE 2 In this standard, cell or secondary cell means the secondary lithium-ion cell to be used for the propulsion of electric road vehicles.

3.7

state of charge

SOC

~~available~~ capacity in a ~~battery~~ cell expressed as a percentage of rated capacity

3.8

charge retention

ability of a cell to retain capacity on open circuit under specified conditions of storage

4 Test conditions

4.1 General

The details of the instrumentation used shall be provided in any report of results.

Test and measurement shall be conducted with caution to prevent a short circuit.

NOTE Test and measurement can be conducted under fixing condition recommended by the cell manufacturer.

4.2 Measuring instruments

4.2.1 Range of measuring devices

The instruments used shall enable the values of voltage, current and temperature to be measured. The range of these instruments and measuring methods shall be chosen so as to ensure the accuracy specified for each test.

For analogue instruments, this implies that the readings shall be taken in the last third of the graduated scale.

Any other measuring instruments may be used provided they give an equivalent accuracy.

4.2.2 Voltage measurement

The resistance of the voltmeters used shall be at least 1 M Ω /V.

4.2.3 Current measurement

The entire assembly of ammeter, shunt and leads shall be of an accuracy class of 0,5 or better.

4.2.4 Temperature measurements

The cell temperature shall be measured by use of a surface temperature measuring device capable of an equivalent scale definition and accuracy of calibration as specified in 4.2.1. The temperature ~~should~~ shall be measured at a location which most closely reflects the cell temperature. The temperature may be measured at additional appropriate locations, if necessary.

The examples for temperature measurement are shown in Figure 1. The instructions for temperature measurement specified by the cell manufacturer shall be followed.

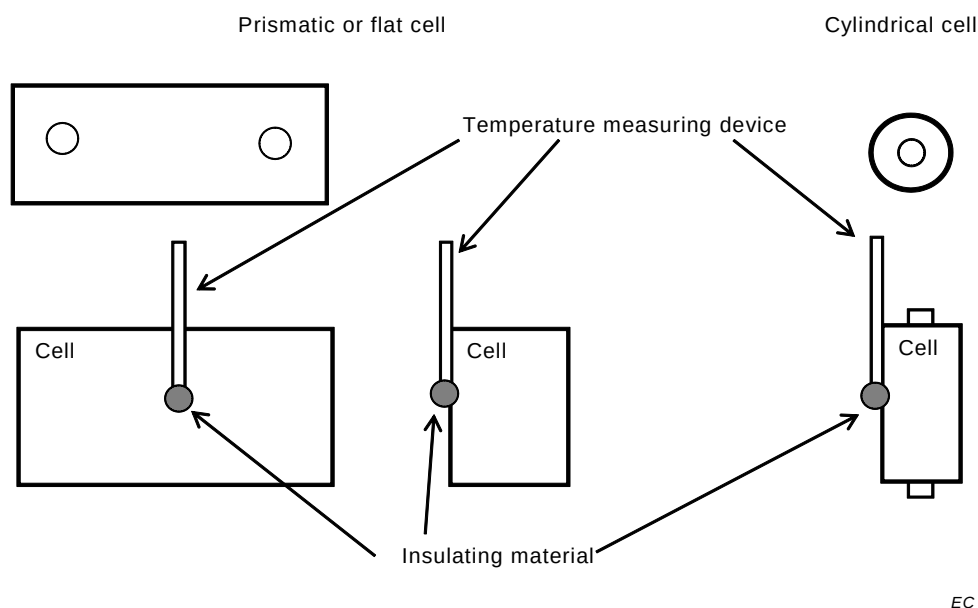


Figure 1 – Example of temperature measurement of cell

4.2.5 Other measurements

Other values ~~including capacity and power~~ may be measured by use of a measuring device, provided that it complies with 4.3.

4.3 Tolerance

The overall accuracy of controlled or measured values, relative to the specified or actual values, shall be within the following tolerances:

- a) $\pm 0,1$ % for voltage;
- b) ± 1 % for current;
- c) ± 2 K for temperature;
- d) $\pm 0,1$ % for time;
- e) $\pm 0,1$ % for mass;
- f) $\pm 0,1$ % for dimensions.

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

~~4.4 Test temperature~~

~~If not otherwise defined, before each test the cell shall be stabilized at the test temperature for a minimum of 12 h. This period can be reduced if thermal stabilization is reached. Thermal stabilization is considered to be reached if after one interval of 1 h, the change of cell temperature is lower than 1 K.~~

~~Unless otherwise stated in this standard, cells shall be tested at room temperature using the method declared by the manufacturer.~~

4.4 Thermal stabilization

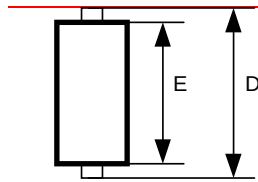
For the stabilization of cell temperature, the cell shall be soaked to a specified ambient temperature for a minimum of 12 h. This period may be reduced if thermal stabilization is

reached. Thermal stabilization is considered to be reached if after one interval of 1 h, the change of cell temperature is lower than 1 K.

5 Dimension measurement

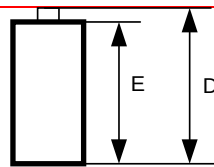
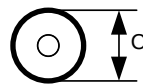
The maximum dimension of the total width, thickness or diameter, and ~~length~~ height of a cell shall be measured at room temperature up to three significant figures in accordance with the tolerances in 4.3.

Examples of maximum dimensions are shown in Figures 2a to 2f.



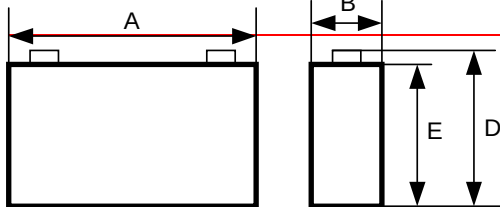
IEC 2862/10

Figure 2a – Cylindrical cell (1)



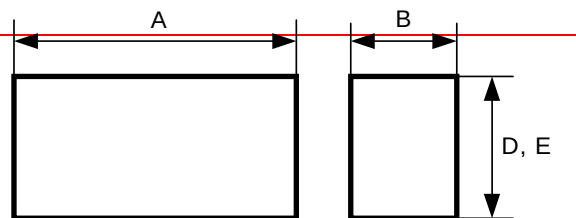
IEC 2863/10

Figure 2b – Cylindrical cell (2)



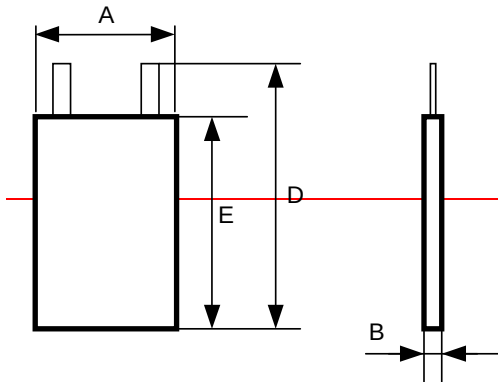
IEC 2864/10

Figure 2c – Prismatic cell (1)



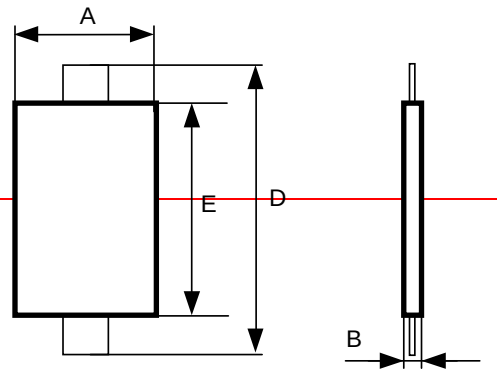
IEC 2865/10

Figure 2d – Prismatic cell (2)



IEC 2866/10

Figure 2e – Flat cell (1)



IEC 2867/10

Figure 2f – Flat cell (2)

Key

A—total width

B—total thickness

C—diameter

D—total length (including terminals)

E—total length (excluding terminals)

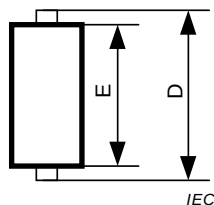
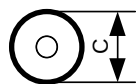


Figure 2a – Cylindrical cell (1)

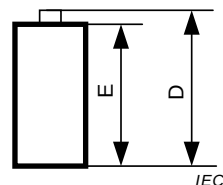
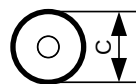


Figure 2b – Cylindrical cell (2)

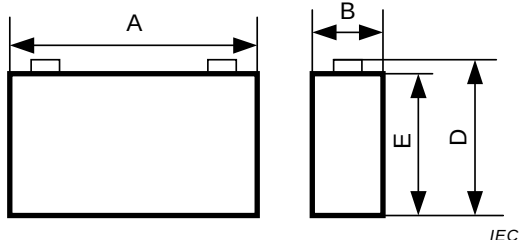


Figure 2c – Prismatic cell (1)

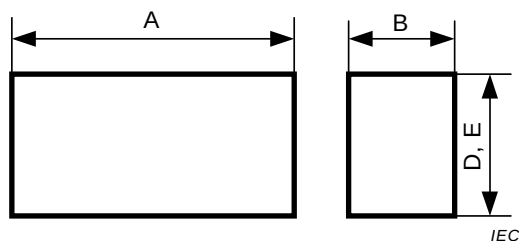


Figure 2d – Prismatic cell (2)

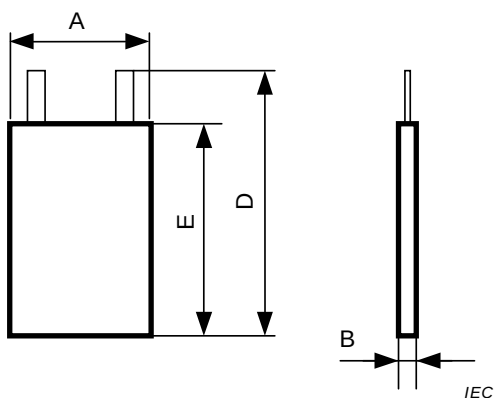


Figure 2e – Prismatic cell with laminate film case (1)

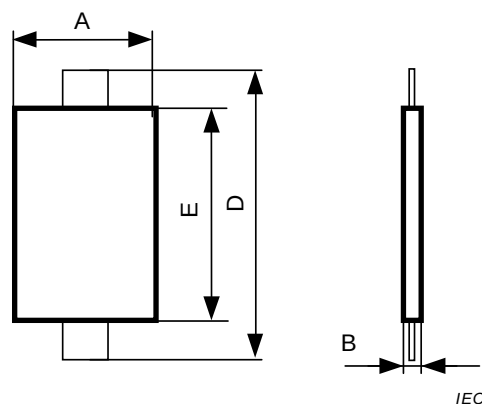


Figure 2f – Prismatic cell with laminate film case (2)

Key

A total width
B total thickness
C diameter

D total height (including terminals)
E total height (excluding terminals)

Figure 2 – Examples of maximum dimensions of cell

NOTE Prismatic cells are provided with either a rigid metal case or flexible laminate film case. A prismatic cell with laminate film case is usually called a pouch cell.

The volume of a prismatic cell is given by the product of its total height excluding terminals, total width, and total thickness, and that of a cylindrical cell is given by the product of the cross section of the cylinder and its total height excluding terminals.

6 Mass measurement

The mass of a cell is measured at room temperature up to three significant figures in accordance with the tolerances in 4.3.

7 Electrical measurement

7.1 General

During each test, voltage, current and temperature shall be recorded.

Before each test, the cell temperature shall be stabilized at room temperature according to 4.4, unless otherwise specified.

The ambient temperature shall be the room temperature unless otherwise specified.

7.2 General charge conditions

Unless otherwise stated in this document, prior to electrical measurement test, the cell shall be charged as follows.

Prior to charging, the cell shall be discharged at room temperature at a constant current described in Table 1 down to an end-of-discharge voltage specified by the cell manufacturer. Then, the cell shall be charged at room temperature according to the charging method declared by the cell manufacturer.

7.3 Capacity

The capacity of a cell shall be measured in accordance with the following phases.

Phase 1 – The cell shall be charged in accordance with 7.2.

After recharge, the cell temperature shall be stabilized in accordance with 4.4.

Phase 2 – The cell shall be discharged at specified temperature at a constant current I_t (A) to the end-of-discharge voltage that is provided by the cell manufacturer. The discharge current and cell temperatures indicated in Table 1 shall be used.

~~NOTE – Selective test conditions are shown in Table A.1 in Annex A.~~

~~The method of designation of test current I_t is defined in IEC 61434.~~

In addition to Table 1, specific test conditions may be selected based on the agreement between the cell manufacturer and the customer. Selective test conditions are shown in Table A.1.

Table 1 – Discharge conditions

Cell temperature °C	Discharge current A	
	BEV application	HEV application
0	$1/3 I_t$	$1 I_t$
25		
45		

Phase 3 – Measure the discharge duration until the specified end-of-discharge voltage is reached. Calculate the capacity of cell expressed in Ah up to three significant figures, by multiplying the discharge current (A) with the discharge duration (h).

7.4 SOC adjustment

The test cells shall be charged as specified below, unless otherwise specified. The SOC adjustment is the procedure to be followed for preparing cells to the various SOC's for the tests in this document.

Phase 1 – The cell shall be charged in accordance with 7.2.

Phase 2 – The cell shall be left at rest at room temperature in accordance with 4.4.

Phase 3 – The cell shall be discharged at a constant current according to Table 1 for $(100 - n)/100 \times 3$ h for BEV application and $(100 - n)/100 \times 1$ h for HEV application, where n is SOC (%) to be adjusted for each test.

7.5 Power

7.5.1 General

This test is intended to determine the power characteristics of a cell under the representative usage conditions of BEV and HEV applications.

Based on the current-voltage characteristic test in 7.5.2, the power density and regenerative power density of a cell shall be calculated according to 7.5.3 and 7.5.4, respectively.

The power density and regenerative power density shall be calculated and reported for each combination of SOC and temperature in 7.5.2.

7.5.2 Test method

The test shall be carried out in accordance with the following procedure.

a) Mass measurement

Mass of the cell shall be measured as specified in Clause 6.

b) Dimension measurement

Dimensions of the cell shall be measured as specified in Clause 5.

c) SOC and temperature adjustment

The test in 7.5.2 d) shall be conducted under each combination of SOC and cell temperature at the test commencement as specified in Table 2, according to the procedure specified by the cell manufacturer.

SOC shall be adjusted according to 7.4.

Table 2 – SOC and temperature condition for power test

SOC %	Cell temperature °C			
20	25			
50	-20	0	25	40
80	25			

NOTE Selective test conditions are shown in Table A.2.

d) Current-voltage characteristics test

~~Current-voltage characteristics shall be determined by measuring the voltage at the end of the 10 s pulse, when a constant current is discharged and charged under the conditions specified below.~~

- ~~1) SOC shall be adjusted to 20 %, 50 %, and 80 % according to the procedure specified in 7.3.~~
- ~~2) The cell temperature at test commencement shall be set to 40 °C, 25 °C, 0 °C, and –20 °C.~~
- ~~3) The cell is charged or discharged at each value of the current corresponding to the respective rated capacity level, and the voltage is measured at the end of the 10 s pulse. The range of the charge and discharge current shall be specified by the manufacturer, and the standard measurement interval shall be 1 s. If the voltage after 10 s exceeds the discharge lower limit voltage or charge upper limit voltage, the measurement data shall be omitted.~~

~~NOTE The charge/discharge limits at low temperature specified by the manufacturer should be taken into account.~~

~~Table 2 shows examples of charge and discharge current according to the applications. If it is required, the maximum current for charge and discharge is specified by the cell manufacturer ($I_{\max}$). This value can be reduced according to the agreement with the customer. The maximum charge and discharge current can be applied after the measurement at $5 I_t$ for BEV application and $10 I_t$ for HEV application. $I_{\max}$ value changes depending on SOC, test temperature and charge or discharge state.~~

Table 2 — Examples of charge and discharge current

Application	Charge and discharge current				
	A				
BEV	$\frac{1}{3} I_t$	$1 I_t$	$2 I_t$	$5 I_t$	$I_{\max}$
HEV	$\frac{1}{3} I_t$	$1 I_t$	$5 I_t$	$10 I_t$	$I_{\max}$

- ~~4) 10 min rest time shall be provided between charge and discharge pulses as well as between discharge and charge pulses. However, if the cell temperature after 10 min is not within 2 K of test temperature, it shall be cooled further; alternatively, the rest time duration shall be extended and it shall be inspected whether the cell temperature then settles within 2 K. The next discharging or charging procedure is then proceeded with.~~
- ~~5) The test is performed according to the scheme shown in Figure 3a and Figure 3b.~~

~~NOTE 1 Selective test conditions are shown in Table A.2 in Annex A.~~

~~NOTE 2 The current-voltage characteristic line can be obtained by straight-line approximation using the measured values of current and voltage, from which $I_{\max}$ and power can be calculated. The slope of this line shows the internal resistance of cell.~~

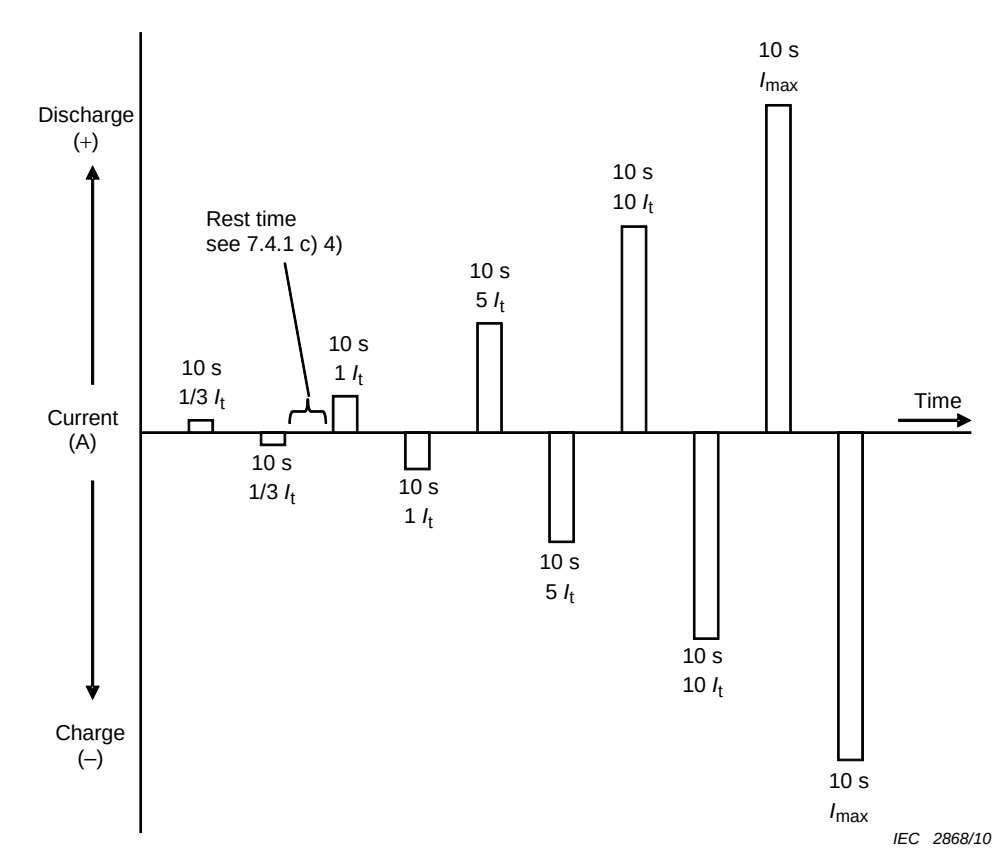


Figure 3a—Test order of the current-voltage characteristic test for HEV application

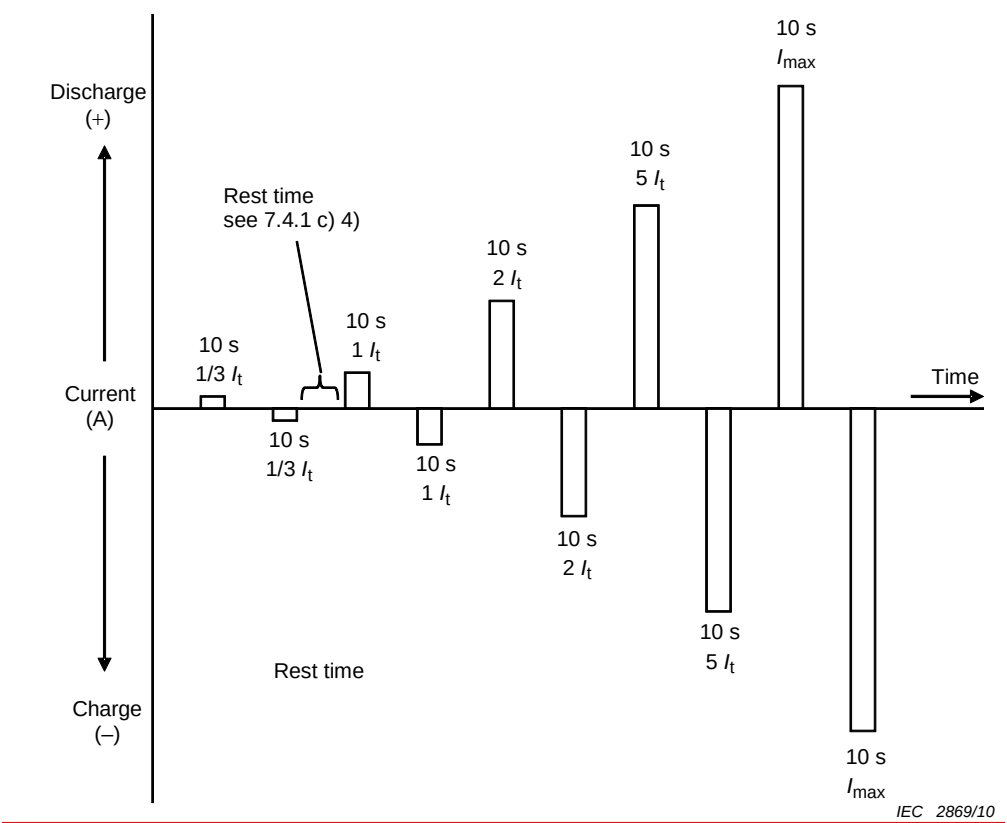


Figure 3b—Test order of the current-voltage characteristic test for BEV application

Figure 3—Test order of the current-voltage characteristic test

Discharge the cell for 10 s at the maximum current for discharge specified by the cell manufacturer (I_{dmax}), and measure the voltage at the end of the 10 s pulse (U_d).

Charge the cell for 10 s at the maximum current for charge specified by the cell manufacturer (I_{cmax}), and measure the voltage at the end of the 10 s pulse (U_c).

The values of I_{dmax} and I_{cmax} change depending on SOC, test temperature and charge or discharge state.

The charge and discharge limits of current and voltage at low temperature specified by the cell manufacturer should be taken into account.

In case that I_{dmax} and I_{cmax} are not available, the value may be obtained according to the test in Annex C.

7.5.3 Calculation of power density

7.5.3.1 Power calculation

The power shall be calculated according to Equation (1) and is rounded to three significant figures.

$$P_d = U_d \times I_{dmax} \quad (1)$$

where

P_d is the power (W);

U_d is the measured voltage at the end of the 10 s pulse of I_{dmax} discharge (V);

I_{dmax} is the maximum discharge current which is specified by the cell manufacturer (A).

If P_d is an estimated value, this shall be stated.

7.5.3.2 Power density per unit mass

Mass power density ~~is~~ shall be calculated from Equation (2), and is rounded to three significant figures.

$$\rho_{pd} = \frac{P_d}{m} \quad (2)$$

where

ρ_{pd} is the power density (W/kg);

P_d is the power (W);

m is the mass of the cell (kg).

7.5.3.3 Power density per unit volume

Volumetric power density shall be calculated from Equation (3), and is rounded to three significant figures.

$$\rho_{pvm} = \frac{P_d}{V} \quad (3)$$

where

ρ_{pvm} is the volumetric power density (W/l);

P_d is the power (W);

V is the volume of the cell (l).

~~The volume of a prismatic or a flat cell is given by the product of its total height excluding terminals, width, and length, and that of a cylindrical cell is given by the product of the cross section of the cylinder and its total length excluding terminals.~~

7.5.4 Calculation of regenerative power density

7.5.4.1 Regenerative power

Regenerative power shall be calculated according to Equation (4) and is rounded to three significant figures.

$$P_c = U_c \times I_{cmax} \quad (4)$$

where

P_c is the regenerative power (W);

U_c is the measured voltage at the end of the 10 s pulse of I_{cmax} charge (V);

I_{cmax} is the maximum charge current specified by the cell manufacturer (A).

If P_c is an estimated value, this shall be stated.

7.5.4.2 Regenerative power density per unit mass

Regenerative power density per unit mass shall be calculated from Equation (5) and is rounded to three significant figures.

$$\rho_{pc} = \frac{P_c}{m} \quad (5)$$

where

ρ_{pc} is the regenerative power density (W/kg);

P_c is the regenerative power (W);

m is the mass of the cell (kg).

7.5.4.3 Regenerative power density per unit volume

Volumetric regenerative power density ~~is~~ shall be calculated from Equation (6) and is rounded to three significant figures.

$$\rho_{pvlmc} = \frac{P_c}{V} \quad (6)$$

where

ρ_{pvlmc} is the volumetric regenerative power density (W/l);

P_c is the regenerative power (W);

V is the volume of the cell (l).

~~The volume of a prismatic or a flat cell is given by the product of its total height excluding terminals, width, and length, and that of a cylindrical battery is given by the product of the cross section of the cylinder and its total length excluding terminals.~~

7.6 Energy

7.6.1 General

This test is intended to determine the energy density that can be derived from a cell under the representative usage conditions of BEV and HEV applications.

Based on the test in 7.6.2, the energy density of a cell shall be calculated according to 7.6.3.

7.6.2 Test method

Mass energy density (Wh/kg) and volumetric energy density (Wh/l) of cells in a certain current discharge of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application shall be determined according to the following procedure.

a) Mass measurement

Mass of the cell shall be measured as specified in Clause 6.

b) Dimension measurement

Dimensions of the cell shall be measured as specified in Clause 5.

c) Capacity measurement

Capacity of the cell shall be determined in accordance with 7.3 at room temperature.

d) Average voltage calculation

The value of the average voltage during discharging in the above capacity test shall be obtained by integrating the discharge voltage over time and dividing the result by the discharge duration. The average voltage is calculated in a simple manner using the following method: Discharge voltages $U_1, U_2, \dots, U_n$ are noted every 5 s from the time the discharging starts and voltages that cut off the end-of-discharge voltage in less than 5 s are discarded. The average voltage U_{avr} is then calculated in a simplified manner using Equation (7) up to three significant figures by rounding off the result.

$$U_{avr} = \frac{U_1 + U_2 + \dots + U_n}{n} \quad (7)$$

~~NOTE—Values provided by measurement devices may be used, if sufficient accuracy can be achieved.~~

7.6.3 Calculation of energy density

7.6.3.1 Energy density per unit mass

The mass energy density shall be calculated using Equation (8) and Equation (9) up to three significant figures by rounding off the result.

$$W_{ed} = C_d U_{avr} \quad (8)$$

where

W_{ed} is the electric energy of the cell at room temperature (Wh) when discharged under specified conditions;

C_d is the discharge capacity (Ah) at $1/3 I_t$ (A) for BEV or $1 I_t$ (A) for HEV;

U_{avr} is the average voltage during discharging (V).

$$\rho_{ed} = \frac{W_{ed}}{m} \quad (9)$$

where

ρ_{ed} is the mass energy density (Wh/kg);

W_{ed} is the electric energy of the cell at room temperature (Wh) when discharged under specified conditions;

m is the mass of the cell (kg).

7.6.3.2 Energy density per unit volume

The volumetric energy density shall be calculated using Equation (10) up to three significant figures by rounding off the result.

$$\rho_{evlmd} = \frac{W_{ed}}{V} \quad (10)$$

where

ρ_{evlmd} is the volumetric energy density (Wh/l);

W_{ed} is the electric energy of the cell at room temperature (Wh) when discharged under specified conditions;

V is the volume of the cell (l).

~~The volume of prismatic cell shall be given by the product of the total height excluding terminals, width, and length of the cell, and that of cylindrical cells shall be given by the product of the cylindrical cross-sectional area and the total length excluding terminals.~~

7.7 Storage test

7.7.1 General

This test is intended to determine the capacity retaining characteristics of a cell under storage or non-use, and is composed of the charge retention test in 7.7.2 and the storage life test in 7.7.3.

7.7.2 Charge retention test

This test is intended to determine the charge retention characteristics of a cell under storage including transportation.

The charge retention characteristics of the cell at a 50 % SOC shall be determined according to the following procedure.

Phase 1 – The cell shall be charged in accordance with 7.2.

Phase 2 – The cell shall be discharged to 50 % SOC in accordance with the method specified in 7.4. Then, the cell shall be stabilized at ~~test~~ room temperature for 1 h.

NOTE The SOC value can be changed according to the agreement between the customer and the cell manufacturer.

Phase 3 – Discharge the cell to the end-of-discharge voltage at a discharge current of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application and at room temperature. This discharge capacity is C_b .

Phase 4 – Repeat phases 1 and 2 one time.

Phase 5 – The cell shall be stored for 28 days at an ambient temperature of $45\text{ }^{\circ}\text{C} \pm 2\text{ K}$.

Phase 6 – After phase 5, the cell shall be stabilized at room temperature according to 4.4. Then, discharge the cell at a constant current of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application ~~at room temperature~~ until the end-of-discharge voltage, and then measure the capacity of cell. This discharge capacity is C_r .

Charge retention ratio shall be calculated according to Equation (11).

$$R = \frac{C_r}{C_b} \times 100 \quad (11)$$

where

R is the charge retention ratio (%);

C_r is the capacity of the cell after storage (Ah);

C_b is the capacity of the cell before storage (Ah).

7.7.3 Storage life test

This test is intended to determine the degradation characteristics of a cell under the storage or non-use of BEV and HEV applications.

The storage life of a cell shall be determined according to the following procedure.

Phase 1 – Determine the capacity, power density and regenerative power density of the cell in accordance with 7.2, 7.3 and 7.5.

Phase 2 – Adjust the SOC of the cell to 100 % for BEV application, and to 50 % for HEV application in accordance with 7.4. The cell shall then be stored for 42 days at an ambient temperature of $45^\circ\text{C} \pm 2\text{ K}$.

Phase 3 – Following the storage of phase 2, the cell shall be ~~kept~~ stabilized at room temperature according to 4.4 and discharged at a constant current of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application, down to the end-of-discharge voltage specified by the cell manufacturer. Then, measure the capacity of the cell. This discharge capacity is the retained capacity (Ah). The power density and regenerative power density shall also be measured.

Phase 4 – Repeat ~~step1~~, phase 2 and phase 3 for three times.

The capacity, power density, regenerative power density and retained capacity measured in phase 1 and phase 3 shall be reported.

If the cell is stored at room temperature during the test for rest such as for test timing adjustment, the total time of such rest shall be reported.

7.8 Cycle life test

7.8.1 General

~~The cycle life test shall be performed~~ This test is intended to determine the degradation characteristics of the cell by charge and discharge cycles representing the normal usage conditions of BEV and HEV applications.

The cycle life performance of a cell for BEV application and HEV application shall be determined according to the tests in 7.8.2 and 7.8.3.

~~NOTE~~ The ~~cycle life~~ test sequence is shown in Annex B.

NOTE Selective test conditions are shown in Table A.3.

7.8.2 BEV cycle test

7.8.2.1 Measurement of initial performance

Before the charge and discharge cycle test, measure the capacity, dynamic discharge capacity, and power as the initial performance of the cell.

- Capacity

The capacity shall be measured as specified in 7.3 at 25 °C ~~± 2 K~~.

- Dynamic discharge capacity C_D

The dynamic discharge capacity C_D shall be measured at 25 °C ~~± 2 K~~ and 45 °C ~~± 2 K~~.

The dynamic discharge capacity is defined by the time integrated value of charge and discharge current confirmed by the following test: Discharge the fully charged cell repeatedly by the dynamic discharge profile A specified in Table 3 and Figure 3 until the voltage reaches the lower limit specified by the cell manufacturer.

- Power

The power shall be measured as specified in 7.5 at 25 °C ~~± 2 K~~ and 50 % SOC.

7.8.2.2 Charge and discharge cycle

The charge and discharge cycle test shall be performed as follows.

~~a) Temperature~~

~~The ambient temperature shall be 45 °C ± 2 K. At the start of charge and discharge cycle, cell temperature shall be 45 °C ± 2 K.~~

~~b) Charge and discharge cycle~~

~~A single cycle is determined as the repetition of the following steps from 1 to 4. The rest time between each step shall be less than 4 h.~~

a) At the start of the test, cell temperature shall be 45 °C. The ambient temperature shall be 45 °C.

b) Test phases

~~The cycle~~ The procedure from phase 1 to phase 5 shall be continuously repeated for 28 days. The rest time of less than 4 h can be set between each phase. Then, measure the performance of the cell as specified in 7.8.2.2 c). This procedure shall be repeated until the test termination specified in 7.8.2.2 d).

Phase 1 – The cell shall be fully discharged by the method specified by the cell manufacturer.

Phase 2 – The cells shall be fully charged by the method specified by the cell manufacturer. The charge time shall be less than 12 h.

Phase 3 – Discharge the cell following the dynamic discharge profile A specified in Table 3 and Figure 3 until the discharged capacity reaches equivalent to 50 % ± 5 % of the initial dynamic discharge capacity C_D at 45 °C.

If the voltage reaches the lower limit specified by the cell manufacturer during phase 3, the test shall be discontinued notwithstanding the stipulation in 7.8.2.2 d), and the cell performance shall be measured at this point as specified in 7.8.2.2 c).

If the temperature of the cell reaches the upper limit specified by the cell manufacturer during phase 3, the duration of ~~charge/discharge~~ test step 20 in Table 3 ~~can~~ may be extended to an appropriate value. The actual duration time shall be reported.

If the voltage reaches the maximum limit specified by the cell manufacturer during a charge step in Table 3, constant-voltage charge at the maximum voltage shall be applied until the end of duration of this step.

In this profile, the test power shall be calculated using Equation (12):

$$P_{\max} = NW_{\text{ed}} \quad (12)$$

where

$P_{\max}$ is the test power (W);

N is ~~a value (1/h) of vehicle required maximum power of cell~~ the required maximum cell power (W) divided by the energy of the cell (Wh) with units of (1/h).

NOTE The value of $N = 3/\text{h}$ is an example based on the specifications of commercialized BEVs.

W_{ed} is the electric energy of the cell at room temperature (Wh) when discharged under specified conditions.

If the value derived from Equation (12) is larger than the maximum power of the cell specified by the cell manufacturer, the test power shall be defined as 80 % of the maximum power at room temperature and at 20 % SOC specified by the cell manufacturer. The power value actually used shall be reported.

Table 3 – Dynamic discharge profile A for BEV cycle test

Charge/discharge Test step	Duration s	Ratio to test power %	Charge/discharge
1	16	0,0	–
2	28	+12,5	Discharge
3	12	+25,0	Discharge
4	8	–12,5	Charge
5	16	0,0	–
6	24	+12,5	Discharge
7	12	+25,0	Discharge
8	8	–12,5	Charge
9	16	0,0	–
10	24	+12,5	Discharge
11	12	+25,0	Discharge
12	8	–12,5	Charge
13	16	0,0	–
14	36	+12,5	Discharge
15	8	+100,0	Discharge
16	24	+62,5	Discharge
17	8	–25,0	Charge
18	32	+25,0	Discharge
19	8	–50,0	Charge
20	44	0,0	–

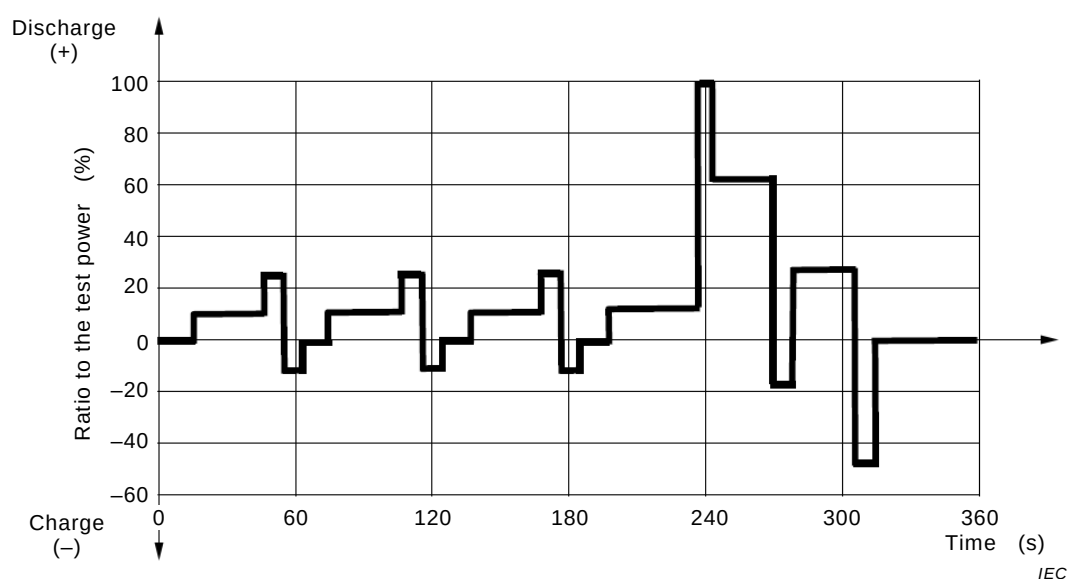


Figure 3 – Dynamic discharge profile A for BEV cycle test

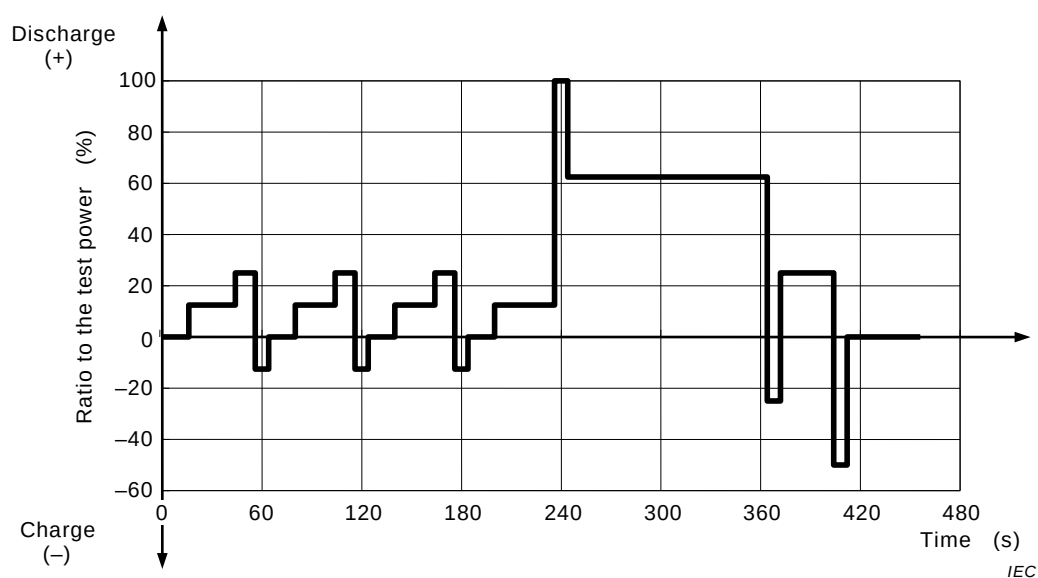
Phase 4 – Discharge the cell following the dynamic discharge profile B (hill climbing profile) specified in Table 4 and Figure 4 for one time. The test power shall be calculated using Equation (12).

If the voltage reaches the lower limit specified by the cell manufacturer during phase 4, the test shall be discontinued notwithstanding the stipulation in 7.8.2.2 d), and the cell performance shall be measured at this point as specified in 7.8.2.2 c).

If the battery voltage frequently reaches the lower limit voltage during ~~charge/discharge~~ test step 16, the discharge power and duration ~~can~~ may be changed appropriately. The actual test values shall be reported accordingly.

Table 4 – Dynamic discharge profile B for BEV cycle test

Charge/discharge Test step	Duration s	Ratio to test power %	Charge/discharge
1	16	0,0	–
2	28	+12,5	Discharge
3	12	+25,0	Discharge
4	8	-12,5	Charge
5	16	0,0	–
6	24	+12,5	Discharge
7	12	+25,0	Discharge
8	8	-12,5	Charge
9	16	0,0	–
10	24	+12,5	Discharge
11	12	+25,0	Discharge
12	8	-12,5	Charge
13	16	0,0	–
14	36	+12,5	Discharge
15	8	+100,0	Discharge
16	120	+62,5	Discharge
17	8	-25,0	Charge
18	32	+25,0	Discharge
19	8	-50,0	Charge
20	44	0,0	–

**Figure 4 – Dynamic discharge profile B for BEV cycle test**

Phase 5 – Discharge the cell following the dynamic discharge profile A specified in Table 3 and Figure 3 until the overall discharge capacity including phase 3 and phase 4 reaches equivalent to 80 % of initial C_D at 45 °C.

If the temperature of the cell reaches the upper limit specified by the cell manufacturer during phase 5, the duration of ~~charge/discharge test~~ step 20 in Table 3 ~~can~~ may be extended to an appropriate value. The actual duration time shall be reported.

If the voltage reaches the lower limit specified by the cell manufacturer during phase 5, the test shall be discontinued notwithstanding the stipulation in 7.8.2.2 d), and the cell performance shall be measured at this point as specified in 7.8.2.2 c).

c) Periodical measurement of performance

After every completion of the repetition from phase 1 to phase 5 for 28 test days, the performance of the cell shall be measured as specified in 7.8.2.1. The accumulated time from phase 1 to phase 4 in 7.8.2.2 b) shall also be reported. The dynamic discharge capacity shall be measured at 25 °C ~~± 2 K~~ only.

d) Termination of test

The cycle life test shall be terminated when either of the following conditions is satisfied. Otherwise, go back to 7.8.2.2 a) and repeat the test.

Condition A – The test sequence from 7.8.2.2 a) to 7.8.2.2 c) ~~is repeated~~ has been performed six times.

Condition B ~~—When~~ Any of the performance parameters measured in 7.8.2.2 c) is decreased to less than 80 % of the initial value.

Condition C – The temperature of cell reaches the upper limit agreed between the cell manufacturer and the customer during the test.

The number of times that each profile and each cycle are implemented during the test shall be reported.

7.8.3 HEV cycle test

~~The cycle life performance of cell for HEV application shall be determined by the following test methods.~~

7.8.3.1 Measurement of initial performance

Before the charge and discharge cycle test, measure the capacity and power as the initial performance of cell.

- Capacity

The capacity shall be measured as specified in 7.3 at 25 °C ~~± 2 K~~.

- Power

The power shall be measured as specified in 7.5 at 25 °C ~~± 2 K~~ and 50 % SOC.

7.8.3.2 Profile switching voltage

Before the cycle life test, set switching voltages at which discharge-rich profile and charge-rich profile specified in 7.8.3.3 c) shall be switched over.

a) Switching voltage from discharge-rich profile to charge-rich profile

Adjust the SOC of the cell to 30 % according to 7.4, and then perform the cycle test with discharge-rich profile at 45 °C for one time. The lowest voltage achieved during this test shall be the switching voltage from discharge-rich profile to charge-rich profile. If the achieved lowest voltage is lower than the cell manufacturer's specified lower limit voltage, the latter shall be the switching voltage. The cell manufacturer's recommended SOC of cell may be used additionally.

b) Switching voltage from charge-rich profile to discharge-rich profile

Adjust the SOC of the cell to 80 % according to 7.4, and then perform the cycle test with charge-rich profile at 45 °C for one time. The highest voltage achieved during this test shall be the switching voltage from charge-rich profile to discharge-rich profile. If the achieved highest voltage is higher than the cell manufacturer's specified upper limit

voltage, the latter shall be used as switching voltage. The cell manufacturer's recommended SOC of cell may be used additionally.

7.8.3.3 Charge and discharge cycle

The charge and discharge cycle test shall be performed as follows.

a) Temperature

The ambient temperature shall be maintained at 45 °C ~~± 2 K in accordance with 4.4~~ during the test. At the start of charge and discharge cycle, cell temperature shall be 45 °C ~~± 2 K in accordance with 4.2.4~~.

b) Adjustment of SOC before charge and discharge cycle

The cells shall be left at a temperature of 45 °C ~~± 2 K~~, and be adjusted to 80 % SOC or the SOC agreed between the cell manufacturer and the customer within an interval of 16 h to 24 h, in accordance with 7.4. If 80 % SOC is not used, the used SOC shall be reported.

c) ~~Charge and discharge cycle~~ Test phases

The procedure from phase 1 to phase 4 shall be continuously repeated until the test termination specified in 7.8.3.3 e). During the test, the performance of the cell shall be measured periodically as specified in 7.8.3.3 d).

If the temperature of the cell reaches the upper limit specified by the cell manufacturer during the test, the duration of ~~charge/discharge test~~ step 16 in Table 5 and Table 6 ~~can~~ may be extended to an appropriate duration time. The actual duration time shall be reported.

Phase 1 – The charge and discharge cycle shall be carried out repeatedly through the discharge-rich profile given by Table 5 and Figure 5 until the cell voltage reaches the switching voltage set in 7.8.3.2 a) (see Figure 7).

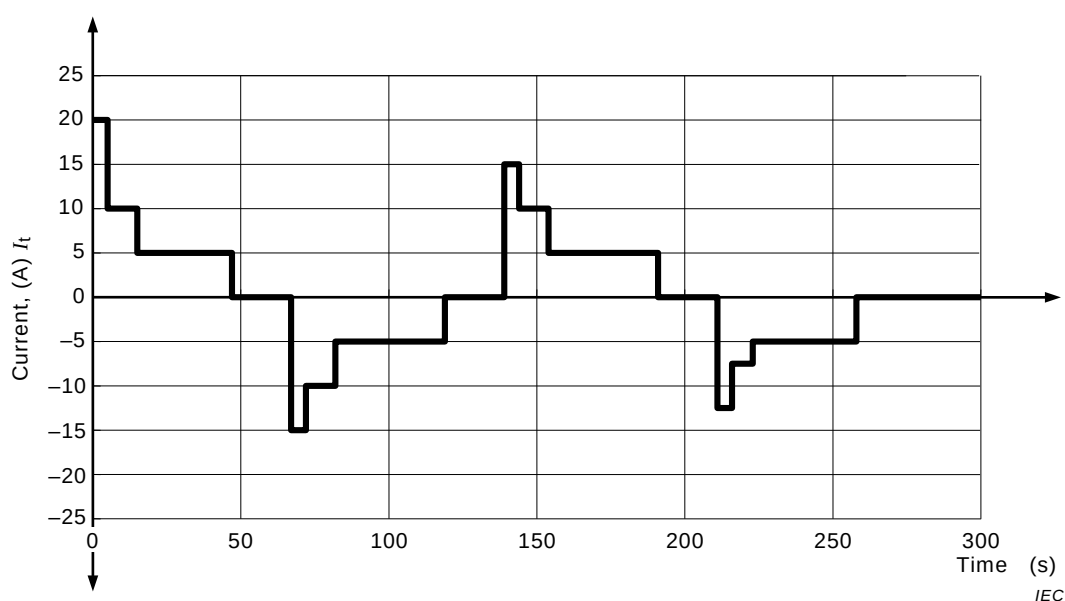
Phase 2 – The charge and discharge cycle shall be carried out repeatedly through the charge-rich profile given by Table 6 and Figure 6 until the cell voltage reaches the switching voltage set in 7.8.3.2 b) (see Figure 7).

Phase 3 – Repeat phase 1 and phase 2 for 22 h.

Phase 4 – Rest the cell for 2 h.

Table 5 – Discharge-rich profile for HEV cycle test

Charge/discharge Test step	Duration s	Current A	Charge/discharge
1	5	$20 I_t$	Discharge
2	10	$10 I_t$	Discharge
3	32	$5 I_t$	Discharge
4	20	$0 I_t$	–
5	5	$-15 I_t$	Charge
6	10	$-10 I_t$	Charge
7	37	$-5 I_t$	Charge
8	20	$0 I_t$	–
9	5	$15 I_t$	Discharge
10	10	$10 I_t$	Discharge
11	37	$5 I_t$	Discharge
12	20	$0 I_t$	–
13	5	$-12,5 I_t$	Charge
14	7	$-7,5 I_t$	Charge
15	35	$-5 I_t$	Charge
16	42	$0 I_t$	–

**Figure 5 – Discharge-rich profile for HEV cycle test**

If the maximum current specified by the cell manufacturer is below $20I_t$, the cell manufacturer's specified maximum current may be used at ~~charge/discharge~~ test step 1, along with replacing the current at ~~charge/discharge~~ test step 6 with 50 % of the cell manufacturer's specified maximum current.

Table 6 – Charge-rich profile for HEV cycle test

Charge/discharge Test step	Duration s	Current A	Charge/discharge
1	5	$-15 I_t$	Charge
2	10	$-10 I_t$	Charge
3	37	$-5 I_t$	Charge
4	20	$0 I_t$	–
5	5	$20 I_t$	Discharge
6	10	$10 I_t$	Discharge
7	32	$5 I_t$	Discharge
8	20	$0 I_t$	–
9	5	$-12,5 I_t$	Charge
10	7	$-7,5 I_t$	Charge
11	49	$-5 I_t$	Charge
12	20	$0 I_t$	–
13	5	$15 I_t$	Discharge
14	10	$10 I_t$	Discharge
15	23	$5 I_t$	Discharge
16	42	$0 I_t$	–

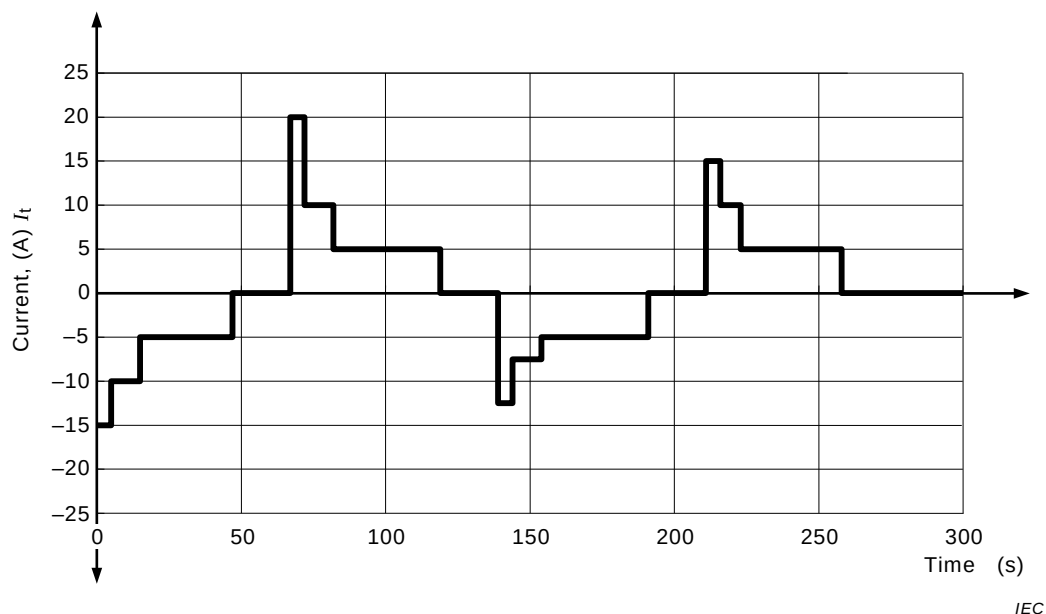


Figure 6 – Charge-rich profile for HEV cycle test

If the maximum current specified by the cell manufacturer is below $20I_t$, the cell manufacturer's specified maximum current may be used at ~~charge/discharge~~ test step 5, along with replacing the current at ~~charge/discharge~~ test step 2 with 50 % of the cell manufacturer's specified maximum current.

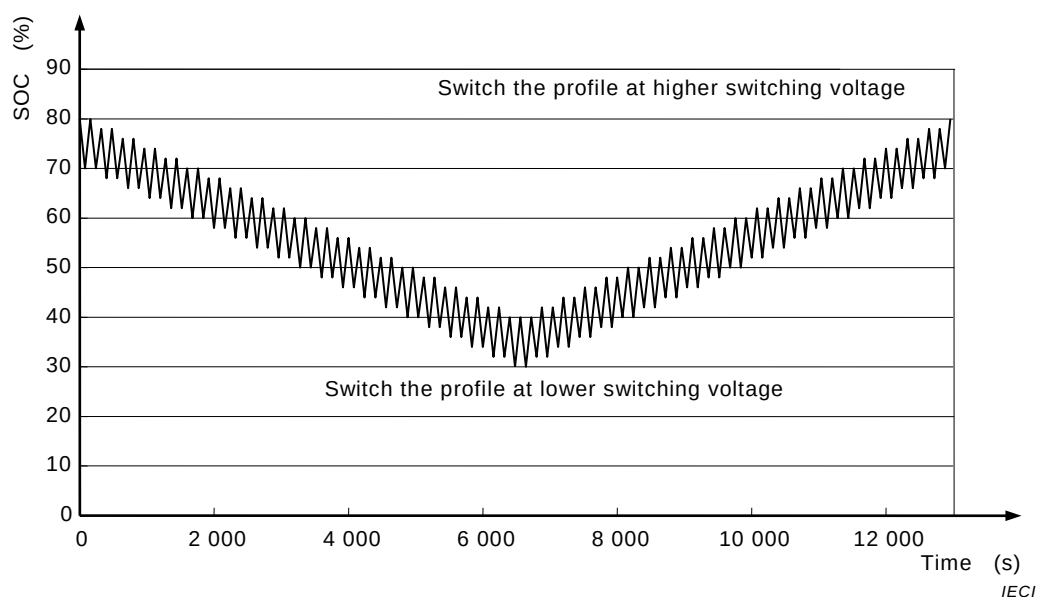


Figure 7 – Typical SOC swing by combination of two profiles for HEV cycle test

d) Periodical measurement of performance

After every completion of the procedure from phase 1 to phase 4 for seven days, the power of the cell shall be measured as specified in 7.8.3.1. The capacity of the cell shall be measured every 14 days as specified in 7.8.3.1.

e) Termination of test

The cycle life test shall be terminated when either of the following conditions is satisfied. Otherwise, go back to 7.8.3.3 a) and repeat the test.

Condition A – The test in 7.8.3.3 c) is repeated for a total of six months.

Condition B – ~~When~~ Either of the performance parameters measured in 7.8.3.3 d) is decreased to less than 80 % of the initial value.

The number of times that each profile is implemented and that the switching voltages are reached shall be reported.

7.9 Energy efficiency test

7.9.1 General

This test is intended to determine the charging efficiency of a cell under the representative usage conditions of BEV or HEV application.

Energy efficiency of cells shall be determined by two common tests as specified in 7.9.2 and either of tests described in 7.9.3 and 7.9.4.

7.9.2 Common tests for BEV and HEV applications

7.9.2.1 Common test for normal conditions

This test aims to determine the efficiency of a cell in normal charging under the representative usage conditions of BEV and HEV applications.

This test is applicable to cells used in HEVs and BEVs. The test shall be carried out in accordance with the following procedure.

- The cell shall be left at rest at room temperature for a minimum of 1 h and a maximum of 4 h after full charge. The test shall then be commenced.
- Discharge the cell by the method specified in 7.3 at room temperature.

c) Energy efficiency test at 100 % SOC:

- 1) leave the cell at rest for 4 h, and then charge it to 100 % SOC by the method recommended by the cell manufacturer;
- 2) leave the cell at rest for 4 h, and then discharge it by the method specified in 7.3 at room temperature.

d) Energy efficiency test at 70 % SOC:

- 1) leave the cell at rest for 4 h, and then charge it to 70 % SOC by the method recommended by the cell manufacturer;
- 2) leave the cell at rest for 4 h, and then discharge it by the method specified in 7.3 at room temperature.

e) Calculation of the discharge electric quantity and charge electric quantity

The electric quantity during the discharge and charge can be calculated using the following method: read the discharge and charge currents I at intervals of s seconds ($s \leq 30$) from the start of the discharge; then, calculate the discharge electric quantity Q_d and charge electric quantity Q_c using Equation (13).

$$Q = \frac{I_1 + I_2 + \dots + I_n}{\frac{3600}{s}} \quad (13)$$

where

Q is the discharge electric quantity or charge electric quantity (Ah);

I_n is the discharge current value or charge current value at point n of measured intervals (A).

f) Calculation of the discharge electric energy and charge electric energy.

The electric energy during the discharge and charge can be calculated using the following method: read the discharge currents I and the discharge voltages U at intervals of s seconds ($s \leq 30$) from the start of discharge; then, calculate the discharge electric energy W_d and charge electric energy W_c using Equation (14).

$$W = \frac{I_1 U_1 + I_2 U_2 + \dots + I_n U_n}{\frac{3600}{s}} \quad (14)$$

where

W is the discharge electric energy or charge electric energy (Wh);

I_n is the charge current value or discharge current value at point n of measured intervals (A);

U_n is the discharge voltage value at point n of measured intervals (V).

g) Calculation of energy efficiency

Determine the coulomb efficiency using Equation (15) and the energy efficiency using Equation (16).

$$\eta_c = \frac{Q_d}{Q_c} \times 100 \quad (15)$$

where

η_c is the coulomb efficiency (%);

Q_d is the discharge electric quantity in 7.9.2.1 e) (Ah);

Q_c is the charge electric quantity in 7.9.2.1 e) (Ah).

$$\eta_e = \frac{W_d}{W_c} \times 100 \quad (16)$$

where

η_e is the energy efficiency (%);

W_d is the discharge electric energy in 7.9.2.1 f) (Wh);

W_c is the charge electric energy in 7.9.2.1 f) (Wh).

NOTE—Values provided by measurement devices may be used, if sufficient accuracy can be achieved.

7.9.2.2 Test by temperature

This test is intended to determine the energy efficiency of a cell in normal charging at different temperature conditions.

This test is applicable to cells used in HEVs and BEVs.

The test shall be carried out in accordance with the following procedure at the test temperatures of $-20\text{ }^{\circ}\text{C} \pm 2\text{ K}$, $0\text{ }^{\circ}\text{C} \pm 2\text{ K}$, and $45\text{ }^{\circ}\text{C} \pm 2\text{ K}$.

- a) Full charge at room temperature.
- b) Thermal equilibration of the cell at the test temperature, and start testing after a minimum of 16 h and a maximum 24 h.
- c) Discharge the cell by the method specified in 7.3 at each test temperature.
- d) Energy efficiency test at 100 % SOC:
 - 1) at each test temperature, leave the cell at rest for 4 h, and then charge it to 100 % SOC by the method recommended by the cell manufacturer;
 - 2) leave the battery at rest for 4 h, and then discharge it by the method specified in 7.3.
- e) Calculate discharge electric quantity and charge electric quantity using Equation (13).
- f) Calculate discharge electric energy and charge electric energy using Equation (14).
- g) Calculate coulomb efficiency and energy efficiency using Equation (15) and Equation (16).

NOTE The charge/discharge limits at low temperature specified by the cell manufacturer should be taken into account.

7.9.3 Test for cells of BEV application

This test is applicable to cells used in BEVs, and intended to determine the energy efficiency of a cell under fast charging conditions.

The test shall be carried out in accordance with the following procedure.

- a) The cell shall be left at rest at room temperature for a minimum of 1 h and a maximum of 4 h after full charge. The test shall then be commenced.
- b) Discharge the cell by the method specified in 7.3.
- c) Energy efficiency test at 80 % SOC:
 - 1) leave the cell at rest for 4 h, and then charge it to 80 % SOC at $2I_t$. If the voltage reached the upper limit voltage specified by the cell manufacturer, charging shall be terminated;

NOTE Selective test conditions are shown in Table A.4.

- 2) leave the cell at rest for more than 4 h until the cell has attained the test temperature, and then discharge it by the method specified in 7.3.
- d) Calculate discharge electric quantity and charge electric quantity using Equation (13).

- e) Calculate discharge electric energy and charge electric energy using Equation (14).
f) Calculation of energy efficiency

Determine the coulomb efficiency using Equation (17) and the energy efficiency using Equation (18).

$$\eta_{c1} = \frac{Q_{d1}}{Q_{c1}} \times 100 \quad (17)$$

where

η_{c1} is the coulomb efficiency (%);

Q_{d1} is the discharge electric quantity in 7.9.3 d) (Ah);

Q_{c1} is the charge electric quantity in 7.9.3 d) (Ah).

$$\eta_{e1} = \frac{W_{d1}}{W_{c1}} \times 100 \quad (18)$$

where

η_{e1} is the energy efficiency (%);

W_{d1} is the discharge electric energy in 7.9.3 e) (Wh);

W_{c1} is the charge electric energy in 7.9.3 e) (Wh).

7.9.4 Energy efficiency calculation for cells of HEV application

This test is applicable to cells used in HEVs, and intended to determine the energy efficiency of a cell under representative usage conditions of HEV application.

- a) Calculation of the charge electric energy and discharge electric energy

Calculate the charge and discharge electric energy from the results of the test specified in 7.5 using Equation (19) and Equation (20). Round off the resulting values to three significant figures.

Read current values and voltage values at regular intervals from the current and voltage data collected during the charge and discharge cycles, which correspond to the charge and discharge patterns of duration $10I_t \times 10$ s. Use the standard measurement interval of 1 s. When the battery voltage after 10 s exceeds the discharge lower limit voltage or the charge upper limit voltage, perform the test using the current value in the lower stage of Table 1, and report the current value that was actually observed.

$$W_{c2} = \frac{I_{c1}U_{c1} + I_{c2}U_{c2} + \dots + I_{cn}U_{cn}}{3600} \quad (19)$$

where

W_{c2} is the charge electric energy (Wh);

I_{cn} is the charge current value at point n of measured intervals (A);

U_{cn} is the charge voltage value at point n of measured intervals (V).

$$W_{d2} = \frac{I_{d1}U_{d1} + I_{d2}U_{d2} + \dots + I_{dn}U_{dn}}{3600} \quad (20)$$

where

W_{d2} is the discharge electric energy (Wh);

I_{dn} is the discharge current value at point n of measured intervals (A);

U_{dn} is the discharge voltage value at point n of measured intervals (V).

b) Calculation of energy efficiency

Determine the energy efficiency using Equation (21).

$$\eta_{e2} = \frac{W_{d2}}{W_{c2}} \times 100 \quad (21)$$

where

η_{e2} is the energy efficiency (%);
 W_{d2} is the discharge electric energy (Wh);
 W_{c2} is the charge electric energy (Wh).

Annex A (informative)

Selective test conditions

Annex A provides additional and selective conditions for the capacity test specified in 7.3, the power tests in 7.5, the cycle life test in 7.8, and the energy efficiency test in 7.9.3.

The test conditions "r" in Table A.1, Table A.2, Table A.3 and Table A.4 are specified in this document. In addition, the test conditions "a" may be selected based on the agreement between the cell manufacturer and the customer.

Table A.1 – Capacity test conditions

Application	Discharge current	Cell temperature			
		–20 °C	0 °C	25 °C	45 °C
BEV	0,2 I_t	a	a	a	a
	1/3 I_t	a	r	r	r
	1 I_t	a	a	a	a
	5 I_t	a	a	a	a
HEV	0,2 I_t	a	a	a	a
	1/3 I_t	a	a	a	a
	1 I_t	a	r	r	r
	10 I_t	a	a	a	a
	I_{dmax}	a	a	a	a

If the data deviation is larger than that of 1 I_t and 1/3 I_t , it shall be indicated.

Table A.2 – Power test conditions

Application	SOC	Cell temperature			
		–20 °C	0 °C	25 °C	40 °C
BEV	20 %	a	a	r	a
	50 %	r	r	r	r
	80 %	a	a	r	a
HEV	20 %	a	a	r	a
	50 %	r	r	r	r
	80 %	a	a	r	a

Table A.3 – Cycle life test conditions

Application	Ambient and cell temperature	
	25 °C	45 °C
BEV	a	r
HEV	a	r