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colour inside

Electric double-layer capacitors for use in hybrid electric vehicles – Test methods for electrical characteristics

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ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN HYBRID ELECTRIC VEHICLES – TEST METHODS FOR ELECTRICAL CHARACTERISTICS

FOREWORD

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International Standard IEC 62576 has been prepared by IEC technical committee 69: Electric road vehicles and electric industrial trucks.

This second edition cancels and replaces the first edition published in 2009. This edition constitutes a technical revision.

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

a) information on applicability of this document has been added in Clause 1;
b) the definitions of some terms in Clause 3 have been improved;
c) the description of test procedures in Clause 4 has been clarified;
d) information on endurance cycling test has been added (Annex E).

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

CDV	Report on voting
69/486/CDV	69/539/RVC

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

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

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- withdrawn,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

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INTRODUCTION

The electric double-layer capacitor (~~EDLC~~ capacitor) is used as an ~~promising~~ energy storage system for ~~hybrid electric~~ vehicles ~~(HEVs)~~. ~~EDLC~~ Capacitor-installed ~~HEVs~~ electric vehicles ~~have begun to be~~ are commercialized with an eye to improving fuel economy by recovering regenerative energy, and by peak power assistance during acceleration, etc. Although standards for ~~EDLC~~ capacitors already exists (IEC 62391 series), those for ~~HEVs~~ electric vehicles involve patterns of use, usage environment, and values of current that are quite different from those assumed in the existing standards. Standard evaluation and test methods will be useful for both auto manufacturers and capacitor suppliers to speed up the development and lower the costs of such ~~EDLCs~~ capacitors. With these points in mind, this document aims to provide basic and minimum specifications in terms of the methods for testing electrical characteristics, and to create an environment that supports the expanding market of ~~HEVs~~ electric vehicles and large capacity ~~EDLCs~~ capacitors. Additional practical test items to be standardized should be reconsidered after technology and market stabilization of ~~EDLCs~~ capacitors for ~~HEVs~~ electric vehicles. ~~In terms of~~ Regarding endurance, which is important in practical use, just a basic concept is set forth in the informative annexes.

ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN HYBRID ELECTRIC VEHICLES – TEST METHODS FOR ELECTRICAL CHARACTERISTICS

1 Scope

This document describes the methods for testing electrical characteristics of electric double-layer capacitor cells (hereinafter referred to as "capacitor") used for peak power assistance in hybrid electric vehicles.

All the tests in this document are type tests.

This document can also be applicable to the capacitor used in idling reduction systems (start and-stop systems) for the vehicles.

This document can also be applicable to the capacitor modules consisting of more than one cell.

NOTE Annex E provides information on endurance cycling test.

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 60068-1:1988, *Environmental testing – Part 1: General and guidance*~~
~~Amendment 1(1992)~~

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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**~~
~~**reference temperature**~~
~~reference temperature (°C) to be used in the test~~

3.1
ambient temperature
~~ambient~~ temperature of the air~~ surrounding space~~ in~~ which a~~ the immediate vicinity of a capacitor~~ is placed~~

3.2
applied voltage
voltage (V) applied between the terminals of a capacitor

3.3
calculation end voltage
voltage (V) at a selected end point for calculating the characteristics including capacitance under a state of voltage decrease during discharge

~~**3.4**~~
~~**lower category temperature**~~
~~lowest ambient temperature that a capacitor is designed to operate continuously~~

3.4
calculation start voltage
voltage (V) at a selected start point for calculating the characteristics including capacitance under a state of voltage decrease during discharge

3.5
capacitance
ability of a capacitor to store electrical charge (F)

3.6
charge accumulated electrical energy
amount of charged energy (J) accumulated from the beginning to the end of charging

3.7
charge current
I_c
current (A) required to charge a capacitor

3.8
charging efficiency
efficiency under specified charging conditions, and ratio (%) of stored energy to charge accumulated electrical energy

Note 1 to entry: This value is calculated from the internal resistance of a capacitor.

Note 2 to entry: Refer to Formula C.8.

3.9
constant voltage charging
~~method of charging a capacitor at specified voltage continuously~~ charging during which the voltage is maintained at a constant value regardless of charge current or temperature

3.10
discharge accumulated electrical energy
amount of discharged energy (J) accumulated from the beginning to the end of discharging

3.11
discharge current
I_d
current (A) required to discharge a capacitor

3.12
discharging efficiency
efficiency under specified discharging conditions, and ratio (%) of discharge accumulated electrical energy to stored energy

Note 1 to entry: This value is calculated from the internal resistance of a capacitor.

Note 2 to entry: Refer to Formula C.10.

3.13
electric double-layer capacitor
capacitor
device that stores electrical energy using a double layer in an electrochemical cell, and whose positive and negative electrodes are of the same material

Note 1 to entry: The electrolytic capacitor is not included in capacitor of this document.

3.14
energy efficiency
E_f
ratio (%) of discharge accumulated electrical energy to charge accumulated electrical energy under specified charging and discharging conditions

~~**3.15**~~
~~**nominal capacitance**~~
~~C_N~~
~~nominal capacitance value (C_N) to be used in design and measurement condition setting (F), generally, at the reference temperature~~

3.15
internal resistance
combined resistance (Ω) of constituent material specific resistance and inside connection resistance of a capacitor

3.16
maximum power density
P_{dm}
~~maximum power density (W/kg or W/l) that can be recovered from a charged capacitor. Generally, it is calculated by using the internal resistance and the rated voltage~~
greatest electrical power output of a capacitor per mass (W/kg) or volume (W/l)

3.17
nominal internal resistance
R_N
nominal value of the internal resistance (R_N) to be used in design and measurement condition setting (Ω), generally at the ambient temperature

3.18
post-treatment ~~**(recovery)**~~
discharging and storage of a capacitor under specified ambient conditions (temperature, humidity, and pressure) after tests

Note 1 to entry: Generally, post-treatment implies that a capacitor is discharged and stored until its inner temperature attains thermal equilibrium with the surrounding temperature before its electrical characteristics are measured.

3.19
pre-conditioning
charging and discharging and storage of a capacitor under specified ambient conditions (temperature, humidity, and pressure) before testing.

Note 1 to entry: Generally, pre-conditioning implies that a capacitor is discharged and stored until its inner temperature attains thermal equilibrium with the surrounding temperature, before its electrical characteristics are measured.

~~**3.20**~~
~~**voltage treatment**~~
~~voltage application before measurement of a capacitor's electrical characteristics~~

NOTE Generally, this treatment is applied to a capacitor that has been stored for a long time or to a capacitor whose history is not clear.

3.20
rated voltage
U_R
maximum DC voltage (V) that may be applied continuously for a certain time under the upper category temperature to a capacitor so that a capacitor can exhibit specified demand characteristics

Note 1 to entry: This voltage is the setting voltage in capacitor design.

Note 2 to entry: The endurance test using the rated voltage is described in Annex A.

3.21
ambient temperature
temperature of air in the vicinity of the device under test, in this document (25 ± 2) °C

3.22
stored energy
energy (J) stored in a capacitor

3.23
upper category temperature
highest ambient temperature that at which a capacitor is designed to operate continuously

3.24
voltage maintenance characteristics
voltage maintenance characteristics of a capacitor when its terminals are open after charging ability of a capacitor to maintain the voltage, with its terminals open, after a specified time period subsequent to the charging

3.25
voltage maintenance rate
ratio of voltage maintenance
ratio of the voltage at the open-ended terminals to the charge voltage after a specified time period subsequent to the charging of a capacitor

3.27
power density
electrical power per unit mass (W/kg) or per unit volume (W/l) that can be recovered from a charged capacitor

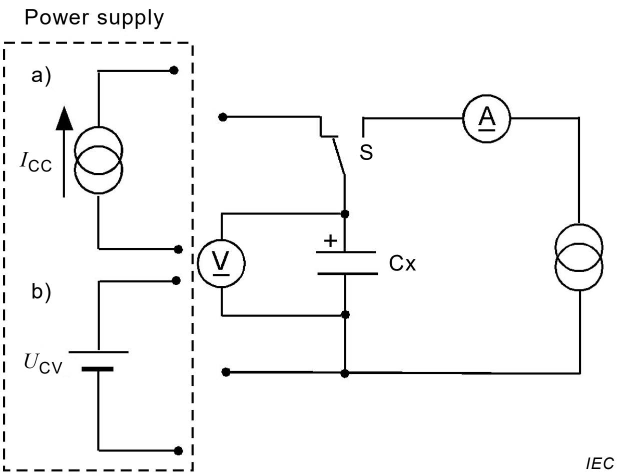
3.28
rated power density
specified maximum power density (W/kg or W/l). Generally, it is calculated by using the nominal internal resistance and the rated voltage

4 Tests and measurement procedures methods

4.1 Capacitance, internal resistance, and maximum power density

4.1.1 Circuit for measurement

The capacitance and the internal resistance shall be measured by using the constant current and constant voltage charging and the constant current discharging methods. Figure 1 shows the basic circuit to be used for the measurement.



Key

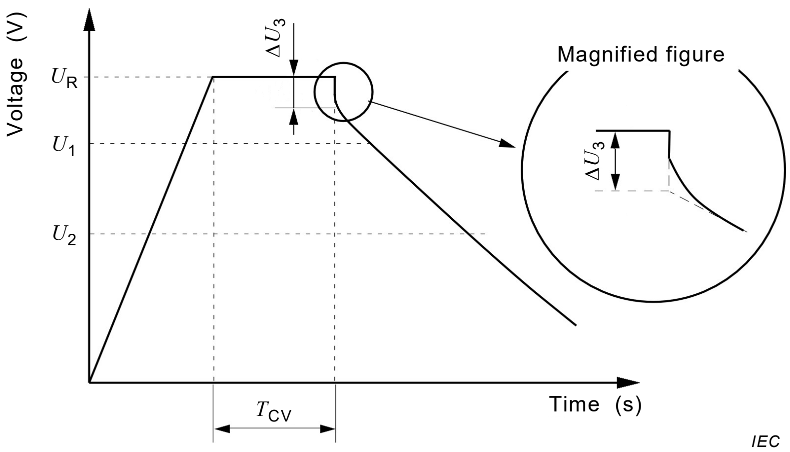
I_{CC}	constant-current
U_{CV}	constant-voltage
(A)	DC ammeter
(V)	DC voltage recorder
S	changeover switch
Cx	capacitor under test
	constant current discharger
a)	constant current charging
b)	constant voltage charging

Figure 1 – Basic circuit for measuring capacitance, internal resistance and maximum power density

4.1.2 Test equipment

The test equipment shall be capable of constant current charging, constant voltage charging, constant current discharging, and continuous measurement of the current and the voltage between the capacitor terminals in time-series as shown in Figure 2. The test equipment shall be able to set ~~and measure~~ the current and the voltage with the accuracy equal to ±1 % or less, and to measure the current and voltage with accuracy equal to ±0,1 %.

The power supply shall provide the constant charge current for the capacitor charge with 95 % efficiency, set the duration of constant voltage charge, and provide a discharge current corresponding to the specified discharge efficiency. The DC voltage recorder shall be capable of conducting measurements and recording with a ~~5 mV resolution and~~ sampling interval of ~~100~~ 10 ms or less.



Key

U_R rated voltage (V)

U_1 calculation start voltage (V)

U_2 calculation end voltage (V)

ΔU_3 voltage drop (V)

T_{CV} constant voltage charging duration (s)

Figure 2 – Voltage–time characteristics between capacitor terminals in capacitance and internal resistance measurement

4.1.3 Measurement procedure

Measurements shall be carried out in accordance with the following procedures using the test equipment specified in 4.1.2.

a) Pre-conditioning

Before measurement, the capacitors shall be fully charged and fully discharged, and then incubated for 2 h to 6 h under the ~~reference~~ ambient temperature~~, set at 25 °C ± 2 °C, as specified in 5.2 in IEC 60068-1,~~ or that specified by the related standards.

NOTE 1 The heat equilibrium time, which provides a reference for the soaking time, is described in Annex B.

NOTE 2 Charging and discharging can be repeated if necessary until the capacity and internal resistance are stabilized.

EXAMPLE

Charge and discharge the sample using the current specified by the manufacturer in the following order:

1) fully discharge;
2) charge up to U_R;
3) discharge down to 0,5 U_R;
4) repeat 2) and 3) ten times.

b) Sample setting

Fit the sample capacitors with the test equipment.

c) Test equipment setup

Unless otherwise specified by related standards, the test equipment shall be set up in the following manner.

1) Set the constant current I_c for charging. At this current, the capacitors shall be able to charge with 95 % charging efficiency based on their nominal internal resistance R_N. The current value is calculated by $I_c = U_R/38R_N$. The constant current value or the charging efficiency may be changed according to the agreement between the customer and the supplier.