BS EN 61881-2:2012

BSI Standards Publication

Railway applications — Rolling stock equipment — Capacitors for power electronics

Part 2: Aluminium electrolytic capacitors with non solid electrolyte

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 61881-2:2012. It is identical to IEC 61881-2:2012.

The UK participation in its preparation was entrusted by Technical Committee GEL/9, Railway Electrotechnical Applications, to Subcommittee GEL/9/2, Railway Electrotechnical Applications - Rolling stock.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2012

ISBN 978 0 580 66267 6

ICS 31.060.70; 45.060

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2012.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 61881-2

September 2012

ICS 45.060

English version

Railway applications - Rolling stock equipment - Capacitors for power electronics - Part 2: Aluminium electrolytic capacitors with non solid electrolyte

(IEC 61881-2:2012)

Applications ferroviaires - Matériel roulant - Condensateurs pour électronique de puissance - Partie 2: Condensateurs électrolytiques à l'aluminium, à électrolyte non solide (CEI 61881-2:2012)

Bahnanwendungen - Betriebsmittel auf Bahnfahrzeugen - Kondensatoren für Leistungselektronik - Teil 2: Aluminium Elektrolytkondensatoren mit nicht festen Elektrolyten (IEC 61881-2:2012)

This European Standard was approved by CENELEC on 2012-09-12. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 9/1679/FDIS, future edition 1 of IEC 61881-2, prepared by IEC/TC 9, "Electrical equipment and systems for railways" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61881-2:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-06-12
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-09-12

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61881-2:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60077-1:1999	NOTE	Harmonized as EN 60077-1:2002 (modified).
IEC 60077-2:1999	NOTE	Harmonized as EN 60077-2:2002 (modified).
IEC 60664-1:2007	NOTE	Harmonized as EN 60664-1:2007 (not modified).
IEC 61287-1:2005	NOTE	Harmonized as EN 61287-1:2006 (not modified).
IEC 61881-1	NOTE	Harmonized as EN 61881-1.
IEC 61881-3	NOTE	Harmonized as EN 61881-3.

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60062	2004	Marking codes for resistors and capacitors	EN 60062 + corr. January	2005 2007
IEC 60068-2-14	2009	Environmental testing - Part 2-14: Tests - Test N: Change of temperature	EN 60068-2-14	2009
IEC 60068-2-17	1994	Environmental testing - Part 2: Tests - Test Q: Sealing	EN 60068-2-17	1994
IEC 60068-2-20	-	Environmental testing - Part 2-20: Tests - Test T: Test methods for solderability and resistance to soldering heat of devices with leads	EN 60068-2-20	-
IEC 60068-2-21 + corr. January	2006 2012	Environmental testing - Part 2-21: Tests - Test U: Robustness of terminations and integral mounting devices	EN 60068-2-21	2006
IEC 60068-2-78	-	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	-
IEC 60384-1 + corr. November	2008 2008	Fixed capacitors for use in electronic equipment - Part 1: Generic specification	EN 60384-1	2009
IEC 60384-4	2007	Fixed capacitors for use in electronic equipment - Part 4: Sectional specification - Aluminium electrolytic capacitors with solid (MnO_2) and non-solid electrolyte	EN 60384-4	2007
IEC 60721-3-5	1997	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 5: Ground vehicle installations	EN 60721-3-5	1997
IEC 61373 + corr. October	2010 2011	Railway applications - Rolling stock equipment - Shock and vibration tests	EN 61373	2010
IEC 62497-1	-	Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment	--	-
IEC 62498-1 + corr. November	2010 2010	Railway applications - Environmental conditions for equipment - Part 1: Equipment on board rolling stock	-	-

CONTENTS

RAILWAY APPLICATIONS – ROLLING STOCK EQUIPMENT – CAPACITORS FOR POWER ELECTRONICS –

Part 2: Aluminium electrolytic capacitors with non-solid electrolyte

1 Scope

This part of IEC 61881 applies to d.c. aluminium electrolytic capacitors (cell, module and bank) for power electronics intended to be used on rolling stock.

This standard specifies quality requirements and tests, safety requirements, and describes installation and operation information.

NOTE Example of the application for capacitors specified in this Standard; d.c. filtering, etc.

Capacitors not covered by this Standard:

– IEC 61881-1: Paper/plastic film capacitors;
– IEC 61881-3: Electric double-layer capacitors.

Guidance for installation and operation is given in Clause 9.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60062:2004, *Marking codes for resistors and capacitors*

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-17:1994, *Environmental testing – Part 2-17: Tests. Test Q: Sealing*

IEC 60068-2-20, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-21:2006, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60384-1:2008, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

IEC 60384-4:2007, *Fixed capacitors for use in electronic equipment – Part 4: Sectional specification – Aluminium electrolytic capacitors with solid (MnO_2) and non-solid electrolyte*

IEC 60721-3-5:1997, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

IEC 61373:2010, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
capacitor element
indivisible electrolytic capacitor with non-solid electrolyte

3.2
capacitor cell
one or more capacitor elements, packaged in the same enclosure with terminals brought out

SEE: Annex A

3.3
capacitor module
assembly of two or more capacitor cells, electrically connected to each other with or without additional electronics

SEE: Annex A

3.4
capacitor bank
assembly of two or more capacitor modules

SEE: Annex A

3.5
capacitor
general term used when it is not necessary to state whether reference is made to capacitor cell, module or bank

[SOURCE: IEC 61881-1:2010, 3, modified]

3.6
capacitor equipment
assembly of capacitor banks and their accessories intended for connection to a network

SEE: Annex A

3.7
capacitor for power electronics
capacitor intended to be used in power electronic equipment and capable of operating continuously under sinusoidal and non-sinusoidal current and voltage

Note 1 to entry: Capacitor in this standard is d.c. capacitor.

3.8
aluminium electrolytic capacitor with non-solid electrolyte
capacitor consisting of oxide film formed on the surface of aluminium foil by anodic oxidation as dielectric and paper or fibber impregnated with liquid electrolyte in close contact with the dielectric as a part of the cathode

3.9
pressure relief structure
mechanism to release internal pressure of capacitor when exceeding the specified value

3.10
discharge device
device which can reduce the voltage between the terminals practically to zero, within a given time, after the capacitor has been disconnected from a network

3.11
rated d.c. voltage (U_R)
maximum d.c. voltage which may be applied continuously to a capacitor at any temperature between the lower category temperature and the upper category temperature

[SOURCE: IEC 60384-1:2008, 2.2.16, modified]

Note 1 to entry: In typical traction application, the maximum voltage is the sum of the d.c. voltage and peak a.c. voltage or peak pulse voltage applied to the capacitor.

3.12
insulation voltage (U_i)
r.m.s. value of the sine wave voltage designed for the insulation between terminals of capacitors to case or earth. If not specified, r.m.s. value of the insulating voltage is equivalent to the rated voltage divided by $\sqrt{2}$

3.13
maximum peak current (I_P)
maximum peak current that can occur during continuous operation

3.14
rated ripple current (I_{ripple})
the r.m.s value of the maximum allowable alternating current of a specified frequency, at which the capacitor may be operated continuously at a specified temperature

3.15
maximum surge current (I_s)
peak non-repetitive current induced by switching or any other disturbance of the system which is allowed for a limited number of times

Note 1 to entry: See surge voltage in IEC 60384-4:2007, 4.14.

3.16
operating temperature
temperature of the hottest point on the case of the capacitor when in steady-state conditions of temperature

SEE: 3.22

3.17
ambient temperature
temperature of the air surrounding the non-heat dissipating capacitor or temperature of the air in free air conditions at such a distance from the heat dissipating capacitor that the effect of the dissipation is negligible

3.18
upper category temperature
highest ambient temperature including internal heating in which a capacitor is designed to operate continuously

3.19
lower category temperature
lowest ambient temperature including internal heating in which a capacitor is designed to operate continuously

3.20
case temperature rise (ΔT_{case})
difference between the temperature of the hottest point of the case and the temperature of the cooling air under the steady-state conditions of temperature

3.21
cooling-air temperature (T_{amb})
temperature of the cooling air measured at the inlet, under the steady-state condition of temperature

3.22
maximum operating temperature (T_{max})
highest temperature of the case at which the capacitor may be operated

Note 1 to entry: The temperature is different from upper category temperature.

3.23
steady-state conditions of temperature
thermal equilibrium attained by the capacitor at constant output and at constant coolant temperature

3.24
tangent of the loss angle of a capacitor
tan
power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage at a specified frequency

[SOURCE: IEC 60384-1:2008, 2.2.24]

$$\tan\delta = \frac{R_{\mathrm{esr}}}{\frac{1}{\omega \mathrm{C}}} = \frac{\mathrm{R}_{\mathrm{esr}}}{\frac{1}{2\pi f \mathrm{C}}} = 2\pi f C \times R_{\mathrm{esr}}$$

where R_{esr} is the equivalent series resistance;
ω is the angular frequency ($2\times\pi\times f$);
C is the capacitance.

3.25
equivalent series resistance of a capacitor (R_{esr})
effective resistance which, if connected in series with an ideal capacitor of capacitance value equal to that of the capacitor in question, would have a power loss equal to active power dissipated in that capacitor under specified operating conditions

4 Service conditions

NOTE See IEC 60077-1.

4.1 Normal service conditions

4.1.1 General

This standard gives requirements for capacitors intended for use in the following conditions:

4.1.2 Altitude

Not exceeding 1 400 m. See IEC 62498-1.

NOTE The effect of altitude on cooling air characteristics and insulation clearance should be taken into consideration, if the altitude exceeds 1 400 m.

4.1.3 Temperature

The climatic ambient temperatures are derived from IEC 60721-3-5:1997 class 5k2 which has a range from –25 °C to 40 °C. Where ambient temperature lies outside this range, it shall be agreed between the purchaser and the manufacturer.

NOTE Classes of temperature are listed in IEC 62498-1:2010, Table 2.

4.2 Unusual service conditions

This standard does not apply to capacitors, whose service conditions are such as to be in general incompatible with its requirements, unless otherwise agreed between the manufacturer and the purchaser.

Unusual service conditions require additional measurements, which ensure that the conditions of this standard are complied with even under these unusual service conditions.

If such unusual service conditions exist then they shall be notified to the manufacturer of the capacitor.

Unusual service conditions can include:

– unusual mechanical shocks and vibrations;
– corrosive and abrasive particles in the cooling air;
– dust in the cooling air, particularly if conductive;
– explosive dust or gas;
– oil or water vapour or corrosive substances;
– nuclear radiation;
– unusual storage or transport temperature;
– unusual humidity (tropical or subtropical region);
– excessive and rapid changes of temperature (more than 5 K/h) or of humidity (more than 5 %/h);
– service areas higher than 1 400 m above sea level;
– superimposed electromagnetic fields;
– excessive over voltages, as far as they exceed the limits given in Clause 6 and in 9.4;
– airtight (poor change of air) installations.

5 Quality requirements and tests

5.1 Test requirements

5.1.1 General

This subclause gives the test requirements for capacitors.

5.1.2 Test conditions

Unless otherwise specified, the test conditions shall be as in IEC 60384-1:2008, 4.2.1.

NOTE IEC 60384-1:2008, 4.2.1 specifies the following standard atmospheric conditions for measurements and tests.

Temperature:	15 °C to 35 °C
Relative humidity:	25 % to 75 %
Air pressure:	86 kPa to 106 kPa.

5.1.3 Measurement conditions

The measurement conditions (i.e. capacitance, tangent of loss angle and leakage current, etc.) for the capacitor shall be as in IEC 60384-4:2007, 4.2.3 with the following exceptions.

The temperature shall be 25 °C ± 2 °C.

Relative humidity shall be 25 % to 75 %.

5.1.4 Voltage treatment

The capacitor shall be subjected to voltage treatment as specified in IEC 60384-4:2007, 4.1. Then the capacitor shall be discharged through a suitable discharge device.

5.1.5 Thermal treatment

The capacitor shall be placed in the environment at the temperature of 5.1.3 for a suitable soak period for thermal equalization.

NOTE Leave time of capacitor to reach measuring condition may be generally 1 h to 4 h for capacitor cell and 4 h to 24 h for capacitor module and bank.

5.2 Classification of tests

5.2.1 General

The tests are classified as type tests, routine tests and acceptance tests:

The type tests and the routine tests consist of tests shown in Table 1.

Table 1 – Classification of tests

No.	Tests item	Type tests		Routine tests	
		Cell	Module or bank	Cell	Module or bank
1A	Capacitance	5.3	5.3	5.3	5.3
1B	Tangent of loss angle	5.3	5.3	5.3	5.3
2	Leakage current	5.4	5.4	5.4	5.4
3	Insulation test between terminals and case	5.5.1[a] (if applicable and required)	5.5.2	5.5.1 [a] (if applicable)	5.5.2
4	Sealing test	5.6	—	—	—
5	Surge discharge test	5.7	5.7 (if applicable)	—	—
6	Change of temperature	5.8.1	5.8.1	—	—
7	Damp heat, steady state	5.8.2 (if applicable)	5.8.2[b] (module only)	—	—
8	Mechanical tests of terminals	5.9.1 [a]	5.9.1 (if applicable)	—	—
9	External inspection	5.9.2	5.9.2	5.9.2	5.9.2
10	Vibration and shocks	5.9.3	5.9.3	—	—
11	Endurance test	5.10	—	—	—
12	Pressure relief test	5.11.1 (if applicable)	—	—	—
13	Passive flammability	5.12	—	—	—

[a] This test may be substituted by module or bank test, when agreed between the manufacturer and the purchaser.

[b] This test may be substituted by capacitor cell test, when agreed between the manufacturer and the purchaser.

5.2.2 Type tests

Type tests are intended to prove the soundness and safety of the design of the capacitor and its suitability for operation under the conditions detailed in this standard.

The type tests shall be carried out by the manufacturer, and the purchaser shall, on request, be supplied with a certificate, detailing the results of such tests.

These tests shall be made upon capacitors which are designed identical to that of the capacitor defined in the contract.

In agreement between the manufacturer and the purchaser, a capacitor of a similar design can be used, when the same or more severe test conditions can be applied.

It is not essential that all type tests be carried out on the same capacitor sample. The choice is left to the manufacturer.

5.2.3 Routine tests

The tests sequence for quality requirements shall be as follows:

Routine tests shall be carried out by the manufacturer on every capacitor before delivery. Upon request, the manufacturer shall deliver the capacitor with certification detailing the results of the tests.

5.2.4 Acceptance tests

All or a part of the type tests and the routine tests may be carried out by the manufacturer, on agreement with the purchaser.

The number of samples that may be subjected to such repeat tests, the acceptance criteria, as well as permission to deliver any of these capacitors shall be subject to agreement between the manufacturer and the purchaser, and shall be stated in the contract.

5.3 Capacitance and tangent of loss angle (tanδ)

5.3.1 Capacitance

The capacitance of the capacitor shall be measured in accordance with IEC 60384-4:2007, 4.3.2 after the leakage current measurement (see 5.4).

The capacitance of the capacitor shall be within the capacitance tolerance agreed between the manufacturer and the purchaser.

5.3.2 Tangent of loss angle (tanδ)

The tangent of loss angle (tanδ) of the capacitor shall be measured in accordance with IEC 60384-4:2007, 4.3.3 after leakage current measurement (see 5.4).

The tangent of loss angle of the capacitors shall not exceed the values agreed between the manufacturer and the purchaser.

5.4 Leakage current

5.4.1 Capacitor cell

Unless otherwise specified, the capacitor cell shall be tested in accordance with IEC 60384-4:2007, 4.3.1 with the following details.

Before this measurement is made, the capacitors cell shall be fully discharged.

The duration of connecting voltage shall be measured in accordance with the time as agreed between the manufacturer and the purchaser.

During the test, neither electrical breakdown of the insulation nor flashover shall occur.

5.4.2 Capacitor module or bank

The capacitor module or bank shall be tested as agreed between the manufacturer and the purchaser.

5.5 Insulation test between terminals and case

5.5.1 Capacitor cell

Unless otherwise agreed between the manufacturer and the purchaser, the measurement for the capacitor shall be in accordance with IEC 60384-1:2008, 4.6.2.3, with the following details:

Measurement section: between the two terminations connected together and non-metallic case of capacitor,

a) test voltage: voltage agreed between the manufacturer and the purchaser;
b) test duration: 1 min, unless otherwise agreed between the manufacturer and the purchaser.

For each of the specified test points there shall be no sign of breakdown or flashover during the test period.

5.5.2 Capacitor module or bank

Unless otherwise specified, the tests of capacitor shall be carried out in accordance with IEC 62497-1 with the following exception:

The test duration shall be 10 s.

5.6 Sealing test

Unless the sealing capability of the capacitor cell has been proved otherwise, the sealing test shall be carried out according to test Qc, method 2 in IEC 60068-2-17:1994, using non-conductive silicon oil or equivalent solvent as an examination solvent.

The capacitor cell shall be immersed in an examination solvent with the sealing parts of the capacitor cell facing up. The temperature of examination solvent shall be 5 °C higher than the operating temperature.

The immersion time for the capacitor cell shall be 3 times or more the thermal time constant for the capacitor cell.

No continuous generation of air bubbles in the examination solvent shall be coming from the sealing parts of the capacitor cell. If the judgment is in doubt, the test shall be performed without sleeve.

5.7 Surge discharge test (under consideration)

5.7.1 General

Unless otherwise specified, the surge discharge test for the capacitor shall be carried out by following procedure.

5.7.2 Preconditioning

The capacitor shall be treated in accordance with 5.1.4 and then 5.1.5.

5.7.3 Initial measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.7.4 Test methods

The capacitor shall be charged by means of a d.c. source up to 1,1 U_R within 5 min and then discharged through a suitable discharge circuit within 1 min. The test shall be repeated 5 times. The test intervals should be within 6 min.

The resistance of the discharge circuit (cables, switches, shunts or electronic) shall have a maximum resistance equal to the internal resistance of capacitor cell, but not higher than 1 mΩ.

If, however, a maximum surge current is specified, the discharge current shall be adjusted by variation of the impedance of discharge circuit to a value of:

$I_{test} = 1{,}1\ I_s$

5.7.5 Post treatment

The capacitor shall be treated in accordance with 5.1.5, and discharged through a suitable discharge device.

5.7.6 Final measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.7.7 Acceptance criteria

The capacitance change of the capacitor shall be within the values agreed between the manufacturer and the purchaser.

The leakage current and tangent of loss angle of the capacitor shall not exceed the values agreed between the manufacturer and the purchaser.

5.8 Environmental testing

5.8.1 Change of temperature

5.8.1.1 General

Unless otherwise specified, the change of temperature test for the capacitor shall be carried out by the following procedure.

5.8.1.2 Preconditioning

The capacitor shall be treated in accordance with 5.1.4 and the 5.1.5.

5.8.1.3 Initial measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.8.1.4 Test methods

The change of temperature test for the capacitor shall be carried out in accordance with test Na of IEC 60068-2-14:2009, on agreement between the manufacturer and the purchaser with the upper and lower limit temperature of the capacitor with following details.

a) Upper limit temperature: Upper category temperature

b) Lower limit temperature: Lower category temperature

c) Number of cycles: As agreed between the manufacturer and the purchaser

5.8.1.5 Post treatment

The capacitor shall be treated in accordance with 5.1.5 and discharged through a suitable discharge device.

5.8.1.6 Final measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.8.1.7 Acceptance criteria

The capacitance change of the capacitor shall be within the values as agreed between the manufacturer and the purchaser.

The leakage current and tangent of loss angle of the capacitor shall not exceed the values as agreed between the manufacturer and the purchaser.

5.8.2 Damp heat, steady state

5.8.2.1 General

Unless otherwise specified, the damp heat, steady state test for the capacitor shall be carried out by the following procedure.

5.8.2.2 Preconditioning

The capacitor shall be treated in accordance with 5.1.4 and 5.1.5.

5.8.2.3 Initial measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.8.2.4 Test methods

The test shall be carried out in accordance with IEC 60068-2-78 and a degree of severity (see Table 2) as agreed between the manufacturer and the purchaser. No condensation shall occur during the test.

Table 2 – Damp heat steady-state test

Severity	Test temperature °C	Test humidity % RH	Duration Days
A	40	93	56
B	40	93	21

After completion of the steady-state test, the capacitor cell (if applicable) or module shall be subjected to insulation test between terminals and case according to 5.5.

5.8.2.5 Post treatment

The capacitor shall be treated in accordance with 5.1.5 and discharged through a suitable discharge device.

5.8.2.6 Final measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.8.2.7 Acceptance criteria

No test sample shall suffer electric break down of insulation or flashover during insulation test between terminals and case (see 5.5).

The capacitance change of the capacitor shall be within the values as agreed between the manufacturer and the purchaser.

The leakage current and tangent of loss angle of the capacitor shall not exceed the values as agreed between the manufacturer and the purchaser.

5.9 Mechanical testing

5.9.1 Mechanical tests of terminals

The capacitor shall be tested for appropriate robustness of terminals as agreed between the manufacturer and the purchaser (see Table 3).

Table 3 – Testing the robustness of terminals

No.	Tests or measurements	Test method		Test conditions
1	Tensile strength of connecting cables and soldered connections	IEC 60068-2-21	Ua_1	Individual with capacitor weight, at least 10 N
2	Flexural strength of connections		Ub_1	Number of flexing cycles: 2
3	Flexural strength of soldering and flat plug lugs		Ub_2	Number of bending cycles, for soldered lugs with connected wire: 2
4	Torsion resistance of axial connections		Uc	Severity 2
5	Torque resistance of screwed and bolted elements		Ud	[a]
6	Solderability and resistance to soldering heat of soldered connections	IEC 60068-2-20		Soldering iron: Size A Bit temperature: 350 °C

[a] The torque resistance of the screwed and bolted connections shall be defined by the manufacturer.

5.9.2 External inspection

The external inspection of the capacitor shall be done by visual examination of finish and marking of the capacitor as agreed between the manufacturer and the purchaser.

5.9.3 Vibration and shocks

Unless otherwise specified, those tests for the capacitor shall be carried out in accordance with IEC 61373:2010, category 1B for capacitor cell and module or category 1A for capacitor bank.

5.10 Endurance test

5.10.1 General

Unless otherwise specified, the endurance test for the capacitor cell shall be carried out by the following procedure.

5.10.2 Preconditioning

The capacitor shall be treated in accordance with 5.1.4 and then 5.1.5.

5.10.3 Initial measurements

The capacitance and tangent of loss angle, and the leakage current of the capacitor cell shall be measured in accordance with 5.3 and 5.4 respectively.

5.10.4 Test methods

Test method for the capacitor cell shall be in accordance with IEC 60384-4:2007, 4.13 with following details:

a) test temperature: upper category temperature;

b) test voltage: pure d.c. voltage equal to U_R;

c) test duration: 2 000 h to 10 000 h (test duration shall be as agreed between the manufacturer and the purchaser).

5.10.5 Post treatment

The capacitor cell shall be treated in accordance with 5.1.5 and discharged through a suitable discharge device.

5.10.6 Final measurement

The capacitance and tangent of loss angle, and the leakage current of the capacitor shall be measured in accordance with 5.3 and 5.4 respectively.

5.10.7 Acceptance criteria

The capacitance change of the capacitor cell shall be within the values as agreed between the manufacturer and the purchaser.

The leakage current and tangent of loss angle of the capacitor cell shall not exceed the values as agreed between the manufacturer and the purchaser.

No visible damage shall be observed.

5.11 Pressure relief test

The pressure relief test for the capacitor cell shall be carried out in accordance with IEC 60384-1:2008, 4.28.2.

NOTE 1 This test is performed to give an indication of the behaviour of the capacitor cell at the end of life and to prove the proper work of the safety system within the specification limits. Completely safe failure during this test cannot be guaranteed.

NOTE 2 As the actual conditions can be significantly different in service, the behaviour at the end of life may also be different. Stored energy, expected short-circuit current, duration of failure current (and so on) should be considered in the application. Compliance does not guarantee safe end of life of a capacitor.

5.12 Passive flammability

The passive flammability test for the capacitor cell shall be carried out in accordance with IEC 60384-1:2008, 4.38.

The capacitor cell shall be held in the flame in the position which best promotes burning. Each capacitor shall be exposed to the flame only once. Test severity (flame exposure time) shall be given by the manufacturer. The maximum burning time of any capacitor cell should not exceed 30 s.

6 Overloads

6.1 Maximum permissible voltage

The capacitor shall be suitable for operation at voltage levels and duration as agreed between the manufacturer and the purchaser without any failure. It should be recognised that any significant period of operation at voltage above the rated voltage will reduce the useful life.

When voltage is applied continuously, the maximum permissible voltage is equal to the rated voltage. When higher voltages than the rated voltage is applied temporarily, the maximum permissible voltage is allowed subject to calculated voltages using rated voltage and surge ratio as defined in IEC 60384-4:2007, 2.2.7 under the conditions as defined in IEC 60384-4:2007, 4.14.

6.2 Maximum permissible current

The capacitor shall be suitable for operation at ripple, charge/discharge and surge current levels and duration as agreed between the manufacturer and the purchaser without any failure. It should be recognised that any significant period of operation at ripple, charge/discharge and surge currents above the rated one will reduce the useful life.

The maximum permissible current shall be as agreed between the manufacturer and the purchaser. For continuous application, the maximum permissible current is ripple current as defined in in 3.14. For instantaneous application, the maximum permissible current are maximum peak current as defined in 3.13 and maximum surge current as defined in 3.15.

7 Safety requirements

7.1 Discharge device

The use of discharge resistors is not suitable for certain power electronic capacitors. When required by the purchaser, each capacitor module and bank shall be provided with means for discharging to 60 V or less, from an initial voltage U_R.

The discharging time shall be agreed upon between the manufacturer and the purchaser.

A discharge device is not a substitute for short-circuiting the capacitor terminals together and to earth before handling.

The capacitors connected directly to other electrical equipment providing a discharge path shall be considered properly discharged, provided that the circuit characteristics are such as to ensure the discharge of the capacitor within the time specified above.

Discharge circuits shall have adequate current-carrying capacity to discharge the capacitor from the peak of the maximum over voltage.

7.2 Case connections (grounding)

To enable the potential of the metal case of the capacitor to be fixed, and to be able to carry the current in the event of an insulation breakdown or flashover to the case, the case shall be provided with a connection or with an unpainted non-corrodible metallic region for a connecting clamp suitable to carry the current.

7.3 Protection of the environment

Precautions shall be taken to not allow dispersion of harmful substances in critical concentrations into the environment. In some countries, there exist legal requirements in this respect.

The purchaser shall specify any special requirements for labelling which apply to the country of installation (see 8.1.2).

If required, the manufacturer shall deliver the fire load or mass of the main components.

NOTE Main components are the components weighing more than 1 % of the capacitors.

7.4 Other safety requirements

The user shall specify at the time of enquiry any special requirements with regard to the safety regulations that apply to the country in which the capacitor is to be installed.

8 Marking

8.1 Marking of the capacitor

8.1.1 Capacitor cell

The following information shall be given on the rating plate of each capacitor cell:

– Manufacturer name (company abbreviation name) or trade mark;
– Product identification number and manufacturing date (year and month or week of manufacture) or serial number;
– C = μF or F;
– Tol* = % or tolerance code as specified in IEC 60062:2004, Clause 5 (optional);
– U_R = V.

NOTE 1 The location of the markings on the capacitor cell should be defined on agreement between the manufacturer and the purchaser.

NOTE 2 For small capacitor cell where it is impracticable to indicate all the above items on the rating plate, certain items may be stated in an instruction sheet.

NOTE 3 Additional data can be added to the rating plate on agreement between the manufacturer and the purchaser.

8.1.2 Capacitor module or bank

The following information shall be given on the rating plate of each capacitor module or bank:

– Manufacturer name (company abbreviation name) or trade mark;
– Product identification number and manufacturing date (year and month or week of manufacture) or serial number;
– C = μF or F;
– Tol* = % or tolerance code as specified in IEC 60062:2004, Clause 5 (optional);
– U_R = V;
– I_s = A (optional);
– T_{max} = °C (optional);
– maximum tightening torque = Nm (see NOTE 2) (optional);
– cooling air temperature (only for forced cooling – see 4.1.3) (optional);
– IEC 61881-2 (optional).

NOTE 1 The location of the markings on the capacitor module or bank should be defined as agreed between the manufacturer and the purchaser.

NOTE 2 For small capacitor module or bank where it is impracticable to indicate all the above items on the rating plate, certain items may be stated in an instruction sheet.

NOTE 3 Additional data can be added to the rating plate as agreed between the manufacturer and the purchaser.

8.2 Data sheet

Information shall be provided by the manufacturer to enable correct operation of the capacitor. If the capacitor cell contains materials that may pollute the environment or may be hazardous in any other way, these materials and their mass shall be declared in the data sheet, according to the relevant laws of the country of the purchaser, who shall inform the manufacturer of such law(s).

Tol *: capacitance tolerance of a capacitor

NOTE 1 Even if the purchaser does not inform the manufacturer of such laws the manufacturer still should observe laws and regulations.

NOTE 2 MSDS with mass percentage may be submitted for the purpose, as agreed between the manufacturer and the purchaser.

9 Guidance for installation and operation

9.1 General

Overstressing shortens the life of a capacitor, and therefore the operating conditions (i.e. temperature, voltage, current and cooling) should be strictly controlled.

Because of the different types of capacitor and many factors involved, it is not possible to cover, using simple rules, installation and operation in all possible cases.

The following information is given with regard to more important points to be considered. In addition, the instructions of the manufacturer and the relevant authorities shall be followed.

The major application:

D.C. harmonic filter generally supplied with a direct voltage superimposed with a non-sinusoidal alternating voltage.

9.2 Choice of rated voltage

The rated voltage of the capacitor shall be equal to or higher than the recurrent peak voltage.

Most of the applications in power electronics show varying loads. Therefore it is necessary that the manufacturer and the purchaser discuss the rated voltage and the true voltage stresses extensively.

NOTE The use of maximum permissible voltage and maximum operating temperature results in reduced lifetime.

9.3 Operating temperature

9.3.1 Life time of capacitor

The life time of the capacitor is affected by the operating temperature, ripple current, applied voltage and the other factors. The manufacturer may provide formula to calculate estimated life under actual operation. However the formula may have some limitation.

Attention should be paid to the operating temperature of the capacitor cell because this has a great influence on its life:

– Excessive temperatures accelerate degradation of the dielectric of capacitor.
– Extremely low temperatures or very rapid changes from hot to cold may initiate partial degradation in the electrolyte or mechanical construction.

9.3.2 Installation

The capacitors shall be so placed that there is adequate dissipation of the heat produced by the capacitor losses.

The temperature of the capacitors subjected to radiation from the sun or from any high temperature surface will be increased.

Depending on the cooling air temperature, the efficiency of the cooling and the intensity and duration of the radiation, it may be necessary to adopt one of the following precautions:

– protect the capacitor from radiation;
– choose a capacitor designed for higher operating air temperature or employ capacitors with rated voltage higher than that laid down in Clauses 4 and 6 and in 9.4;
– the capacitors installed at high altitudes (above 1 400 m) will be subjected to decreasing heat dissipation; this should be considered when determining the power of the equipment.

The manufacturer should deliver a set of thermal values that describes the thermal behaviour of the capacitor hotspot as a function of the ambient temperature, the load cycles and the cooling conditions shall be recommended by the manufacturer.

NOTE Some cylindrical capacitors are equipped with a vent as a pressure relief structure on its end-seal. As for screw terminal type capacitors, the plastics compound is used to fix the internal element in place. The compound may melt when the capacitor is subjected to abnormal heating. If the molten compound clogs the pressure relief vent, it may disturb the vent operation. The screw type capacitor with end-seal having the vent should not be mounted so that the vent is downward. If the capacitors have to be mounted horizontally, the vent and anode terminal should be oriented as shown in Figure 1.

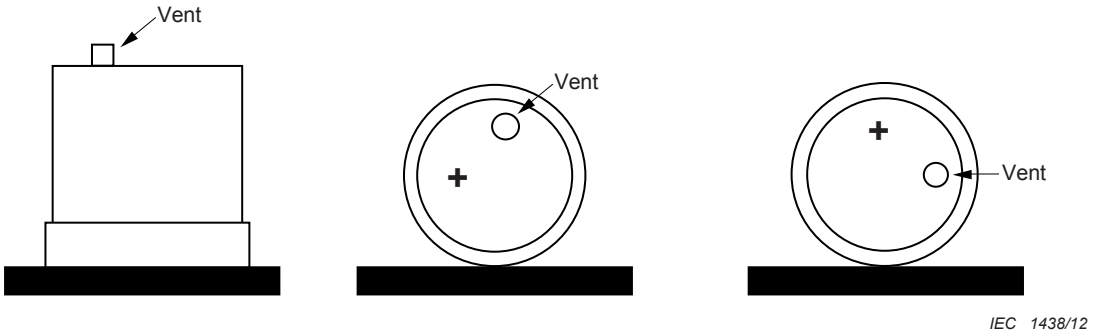

Figure 1 – Examples of preferred vent and anode position

9.3.3 Unusual cooling conditions

In exceptional cases, the ambient temperature may be higher than 40 °C. If this is the case the manufacturer has to take this into account concerning lifetime and safety of operation.

9.4 Over voltages

Transient over voltages during unusual service conditions may enforce the choice of higher rated capacitors.

9.5 Overload currents

The capacitors should never be operated with currents exceeding the maximum values defined in 3.13, 3.14 and 3.15.

Transient over currents of high amplitude and frequency may occur when capacitors are switched into the circuit or the equipment is switched. It may be necessary to reduce these transient over currents to acceptable values in relation to the capacitor and to the equipment.

If the capacitors are provided with external fuses, the peak value of the over currents due to switching operations shall be limited to the value of I_S.

9.6 Switching and protective devices

Switching and protective devices and connections shall be capable of withstanding the electrodynamics and thermal stresses caused by the transient over currents of high amplitude and frequency that may occur when switching on, or otherwise.

If consideration of electrodynamic and thermal stress would lead to excessive dimensions, special precautions, for the purpose of protection against over currents, should be taken.

9.7 Dimensioning of creepage distance and clearance

See IEC 62497-1.

9.8 Connections

The current leads into the capacitor are capable of dissipating heat from the capacitor. Equally they are capable of transferring heat generated in outer connections into the capacitor.

Therefore it is necessary to keep the connections leading to the capacitors at least as cool as the capacitor itself.

Any bad contacts in capacitor circuits may give rise to local heat generation and possibility of arcing at the connection that may overheat and overstress the capacitors.

Regular inspection of all capacitor equipment contacts and capacitor connections is therefore recommended.

9.9 Parallel connections of capacitors

Special care is necessary when designing circuits with capacitors connected in parallel, because of the possible danger that the current splitting depends on slight differences in resistance and inductance in the current paths, so that one of the capacitors may be easily overloaded.

As a consequence, when one capacitor fails by a short circuit, the complete energy of the parallel capacitors will be rapidly dissipated at the point of breakdown.

Special precautions have to be taken in this case.

9.10 Series connections of capacitors

Because of variations in the parameters of capacitors, the correct voltage sharing between capacitor cells should be ensured.

The insulation voltage of the capacitor module or bank shall be chosen for the series arrangement.

Special precautions have to be taken in this case.

9.11 Magnetic losses and eddy currents

The strong magnetic fields of conductors in power electronics may induce alternating magnetization of magnetic cases and eddy currents in any metal part and thereby produce heat. It is therefore necessary to situate capacitors at a safe distance from heavy current conductors and to avoid the use of magnetic materials as far as possible.

9.12 Guide for unprotected capacitors

In case of unprotected capacitors, the purchaser has to ensure by qualified installation that no danger appears due to a failing capacitor.

Annex A
(informative)

Terms and definitions of capacitors

A.1 Capacitor application in capacitor equipment

An example of schematic diagram for capacitor cell (see 3.2), capacitor module (see 3.3) and capacitor bank (see 3.4) used in capacitor equipment (see 3.6) is shown in Figure A.1.

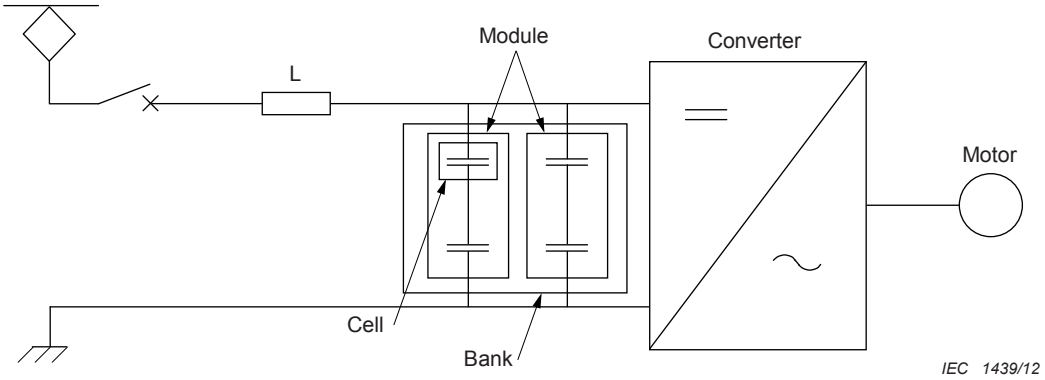

Figure A.1 – Example of capacitor application in capacitor equipment

Bibliography

IEC 60050-436, *International Electrotechnical Vocabulary (IEV) – Part 436: Power capacitors*

IEC 60077-1:1999, *Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules*

IEC 60077-2:1999, *Railway applications – Electric equipment for rolling stock – Part 2: Electrotechnical components – General rules*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60850:2007, *Railway applications – Supply voltages of traction systems*

IEC 61287-1:2005, *Railway applications – Power convertors installed on board rolling stock – Part 1: Characteristics and test methods*

IEC 61881-1, *Railway applications – Rolling stock equipment – Capacitors for power electronics – Part 1: Paper/plastic film capacitors*

IEC 61881-3, *Railway applications – Rolling stock equipment – Capacitors for power electronics – Part 3: Electric double-layer capacitors*

IEC 61991:2000, *Railway applications – Rolling stock – Protective provisions against electrical hazards*

_____

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

bsi.

...making excellence a habit.™