IEC 60384-14

Edition 5.0 2023-01
COMMENTED VERSION

INTERNATIONAL STANDARD

colour
inside

Fixed capacitors for use in electronic equipment –
Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

IEC 60384-14:2023-01 CMV(en)

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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This commented version (CMV) of the official standard IEC 60384-14:2023 edition 5.0 allows the user to identify the changes made to the previous IEC 60384-14:2013+ AMD1:2016 CSV edition 4.1. Furthermore, comments from IEC TC 40 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60384-14 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2013 and Amendment 1:2016. This edition constitutes a technical revision.

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

a) in damp heat steady state test, all capacitor types are tested both with and without rated voltage; the number of test pieces has been increased;
b) tangent of loss angle is added In Group 0 tests, in safety tests only;
c) qualification approval based on safety and performance tests has been removed from the main text to a normative annex;
d) the range of rated voltages is given instead of exact rated voltage values;
e) normative annex for description of capacitor styles and of creepage/clearance distance measurement has been added;
f) the importance of mechanical failures (cracks) in component encapsulation as a safety feature is highlighted in handling instructions and requirements after all relevant tests.

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

Draft	Report on voting
40/2985/FDIS	40/3022/RVD

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

The language used for the development of this International Standard is English.

A list of all the parts of the IEC 60384 series, published under the general title *Fixed capacitors for use in electronic equipment*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

~~1 General~~

1 Scope

This part of IEC 60384 applies to capacitors and resistor-capacitor combinations intended to be connected to AC mains or other supply with a nominal voltage not exceeding 1 000 V AC (RMS) ~~or 1 500 V d.c.~~, and with a nominal frequency not exceeding 100 Hz. This document includes also additional specific conditions and requirements for the connection to DC supplies with a rated voltage not exceeding 1 500 V DC. 1

~~1.2 Object~~

The principal object of this part of IEC 60384 is to prescribe preferred ratings and characteristics and to select, from IEC 60384-1, the appropriate quality assessment procedures, tests and measuring methods and to give general performance requirements for this type of capacitor. Test severities and requirements prescribed in detail specifications referring to this sectional specification are of equal or higher performance level; lower performance levels are not permitted.

This document also provides a schedule of safety tests to be used by national testing stations in countries where approval by such stations is required.

The overvoltage categories in combination with the AC mains voltages for the capacitors classified in this document ~~should~~ are to be taken from IEC 60664-1.

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 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60063, *Preferred number series for resistors and capacitors*

~~IEC 60065:2001, *Audio, video and similar electronic apparatus – Safety requirements*~~
~~Amendment 1:2005~~
~~Amendment 2:2010~~

IEC 60068-1:~~1988~~2013, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-17, *Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing*

IEC 60384-1:~~2008~~2021, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

~~IEC 60417, *Graphical symbols for use on equipment*~~

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

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

~~IEC 60940, *Guidance information on the application of capacitors, resistors, inductors and complete filter units for radio interference suppression*~~

IEC 61193-2:2007, *Quality assessment systems – Part 2: Selection and use of sampling plans for inspection of electronic components and packages*

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

CISPR 17, *Methods of measurement of the suppression characteristics of passive EMC filtering devices*

ISO 7000, *Graphical symbols for use on equipment ~~– Index and synopsis~~* (available at http://www.graphical-symbols.info/equipment)

3 Terms and definitions and classification

3.1 Terms and definitions

For the purposes of this document, the terms, and definitions of IEC 60384-1, as well as the following, apply.

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

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

NOTE Some definitions of IEC 60384-1 have been expanded, as is indicated by a note.

3.1.1
AC capacitor
capacitor designed essentially for application with a power-frequency alternating voltage

Note 1 to entry: AC capacitors may be used on DC supplies having the same voltage as the AC RMS rated voltage of the capacitor. For use of capacitors with rated DC voltage greater than the rated AC voltage, see Annex H.

3.1.2
electromagnetic interference suppression capacitor
radio interference suppression capacitor
AC capacitor used for the reduction of electromagnetic interference caused by electrical or electronic apparatus, or other sources

3.1.3
capacitor of Class X
RC unit of Class X
capacitor or RC unit of a type suitable for use in situations where failure of the capacitor or RC unit would not lead to danger of electrical shock but could result in a risk of fire

3.1.4
capacitor of Class Y
RC unit of Class Y
capacitor or RC unit of a type suitable for use in situations where failure of the capacitor could lead to danger of electric shock

3.1.5
two-terminal capacitor
electromagnetic interference suppression capacitor having two terminals

Note 1 to entry: See Figure 1.

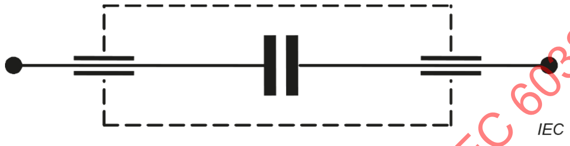


Figure 1 – Two-terminal EMI suppression capacitor

3.1.6
series RC unit
functional combination of a resistor in series with a capacitor of Class X or Y

Note 1 to entry: See Figure 2.

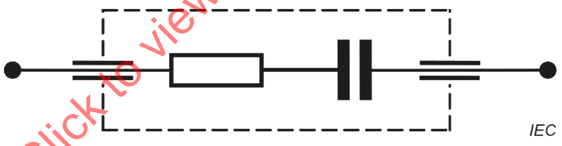


Figure 2 – RC unit

Note 2 to entry: In this document, where the word "capacitor" appears, the words "capacitor or RC unit" should be understood where the context permits.

3.1.7
lead-through capacitor
<coaxial> capacitor with a central current-carrying conductor surrounded by a capacitor element which is symmetrically bonded to the central conductor and to the outer casing to form a coaxial construction

Note 1 to entry: These lead-through capacitors are coaxially mounted (see Figure 3).

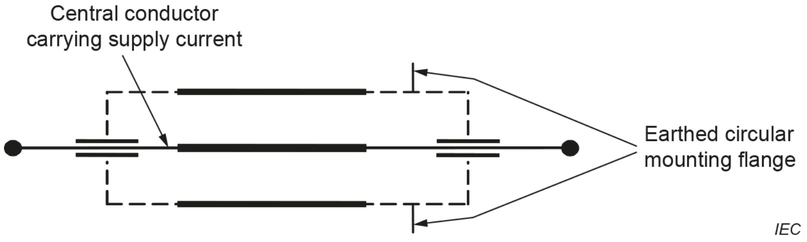
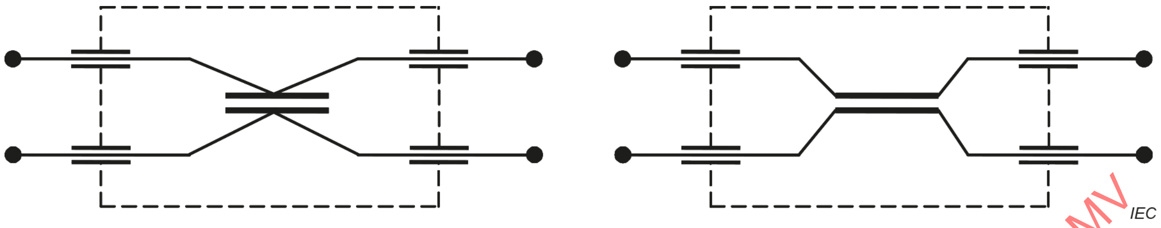


Figure 3 – Lead-through capacitor (coaxial)

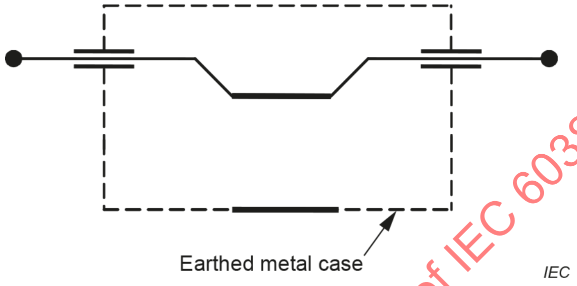
3.1.8
lead-through capacitor

<non-coaxial> capacitor in which the supply currents flow through or across the electrodes

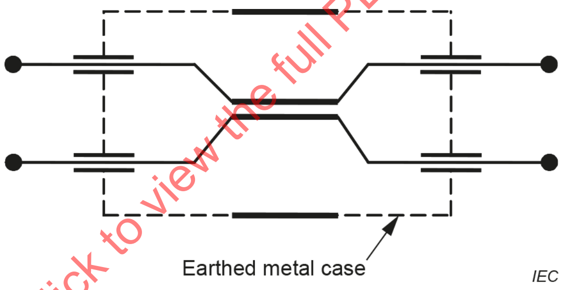
Note 1 to entry: See Figure 4 a), Figure 4 b), Figure 4 c) and Figure 4 d).



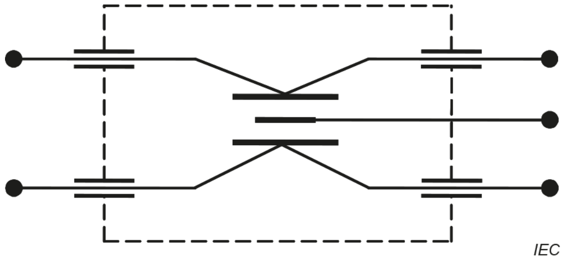
a) Lead-through capacitor for symmetrical use (non-coaxial)



b) Lead-through capacitor for asymmetrical use (non-coaxial)



c) Multiple unit lead-through capacitor (non-coaxial) for symmetrical and asymmetrical use



d) Multiple unit lead-through capacitor

Figure 4 – Lead-through capacitors

3.1.9
by-pass capacitor

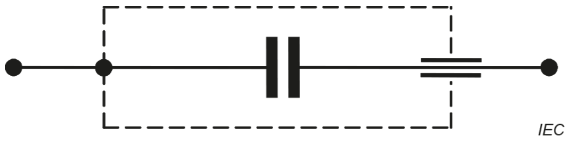
capacitor where radiofrequency interference currents are by-passed

Note 1 to entry: There are three common forms: single, delta and T-connected. The single capacitor consists of a capacitor in a metal case with one termination connected to the case as in Figure 5 a); the delta form consists of an X-capacitor and two Y2-capacitors arranged in a delta network as in Figure 5 b); the T-connected form consists of three capacitors C_A, C_B and C_C connected in T as shown in Figure 5 c).

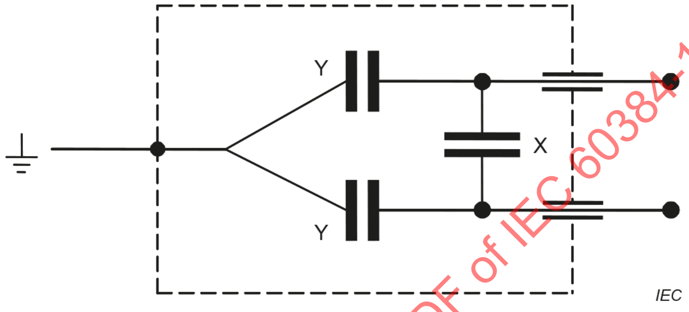
The delta and T-connected forms are electrically equivalent (star-delta transformation). In the T-connected form the X-capacitor is the result of the series connection of C_B – C_C and the Y-capacitors are the results of the series connections of C_A – C_B and C_A – C_C.

When T-connected capacitors are submitted to tests, and it is stated that voltages shall be applied across the X-capacitors, such voltages shall be applied between the line (L) and neutral (N) terminations. Similarly, when it is stated that voltages shall be applied across the Y-capacitors, such voltages shall be applied between the line and neutral terminations connected together and the earth termination.

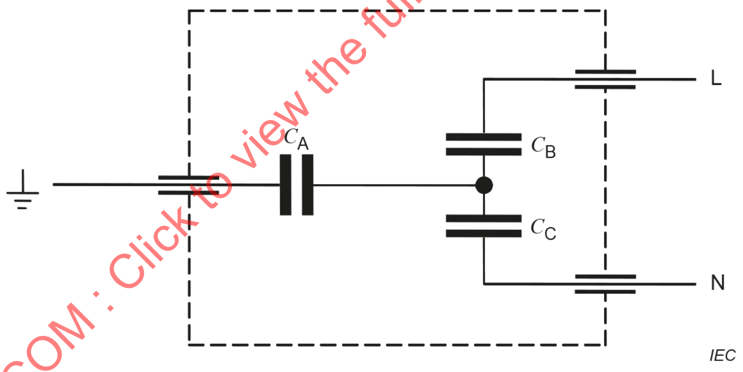
Note 2 to entry: See Figure 5a), Figure 5b) and Figure 5c)



a) **Single by-pass capacitor**



b) **Delta by-pass capacitor (in metallic housing)**



c) **Example of a T-connected by-pass capacitor (in non-metallic housing)**

NOTE For capacitors with non-metallic housings, the earth connection is brought out as a separate termination as is shown in Figure 5c).

Figure 5 – By-pass capacitors

3.1.10
rated voltage

<for capacitor>~~either the~~ RMS operating voltage of rated frequency or the DC operating voltage that~~may~~ can be applied continuously to the terminations of a capacitor at any temperature between the lower and the upper category temperatures

Note 1 to entry: This implies, for capacitors covered by this document, that the category voltage is the same as the rated voltage.

3.1.11
rated DC voltage 2
U_R DC

maximum DC operating voltage, which can be applied continuously to the terminations of a capacitor at any temperature between the lower and the upper category temperatures

Note 1 to entry: This term and designation (U_R DC) are used only for a capacitor specified with rated DC voltage exceeding its rated AC voltage (RMS).

3.1.12
rated power

<of a series RC unit> maximum power that can be dissipated by the RC unit at the rated temperature during continuous operation

3.1.13
upper category temperature

maximum surface temperature for which the capacitor has been designed to operate continuously

Note 1 to entry: For lead-through capacitors and series RC units, the external surface temperature can be affected by internal heating due to the lead-through current. The terminations of a capacitor are considered to be part of the external surface.

Note 2 to entry: This definition replaces that given in IEC 60384-1:~~2008~~2021, 3.41, because suppression capacitors in accordance with this document are intended to be connected to the mains network and ~~may~~ can have internal heat generation as a result.

3.1.14
lower category temperature

minimum surface temperature for which the capacitor has been designed to operate continuously

Note 1 to entry: This definition replaces that given in IEC 60384-1:~~2008~~2021, 3.10.

3.1.15
rated temperature

<of a lead-through capacitor or series RC unit> maximum ambient temperature at which a lead-through capacitor can carry its rated lead-through current or a series RC unit can dissipate its rated power

Note 1 to entry: This definition replaces that given in IEC 60384-1:~~2008~~2021, 3.24.

3.1.16
insertion loss

<for capacitors> ratio of the voltage before and after the insertion of the suppressor as measured at the terminations

Note 1 to entry: When measured in decibels, the insertion loss is 20 times the logarithm to base 10 of the ratio stated.

3.1.17
rated current of the conductor

<of a lead-through capacitor> maximum permissible current flowing through the conductors of the capacitor at the rated temperature during continuous operation

3.1.18
main resonant frequency

<of a two-terminal capacitor> lowest frequency at which the impedance of the capacitor is a minimum when applying a sinusoidal voltage

3.1.19
impulse voltage
periodic transient voltage of a defined waveform as described in IEC 60060-1

3.1.20
passive flammability
ability of a capacitor to burn with a flame as a consequence of the application of an external source of heat

3.1.21
active flammability
ability of a capacitor to burn with a flame as a consequence of electric loading

3.1.22
surface mount capacitor
capacitor whose small dimensions and nature of shape of terminations make it suitable for surface mounting in hybrid circuits and on printed boards

3.2 Classifications

3.2.1 Classification of X capacitors

Class X capacitors are divided into two subclasses (see Table 1) according to the peak voltage of the impulses superimposed on the mains voltage to which they may be subjected in service. Such impulses ~~may~~ can arise from lightning strikes on outside lines, from switching in neighbouring equipment, or switching in the equipment in which the capacitor is used.

Table 1 – Classification of Class X capacitors

Subclass	Peak impulse voltage in service	Application	Peak impulse voltage U_P applied before endurance test	
			$C_N \leq 1{,}0$ µF	$C_N > 1{,}0$ µF
X1	>2,5 kV ≤4,0 kV	High pulse application	4 kV	$U_P = \frac{4}{\sqrt{\frac{C_N}{10^{-6}\ F}}}$ in kV
X2	≤2,5 kV	General purpose	2,5 kV	$U_P = \frac{2{,}5}{\sqrt{\frac{C_N}{10^{-6}\ F}}}$ in kV

X1 capacitors may be substituted by Y2 or Y1 capacitors of the same or higher U_R. X2 capacitors can be substituted with X1 or Y2 or Y1 capacitors of the same or higher U_R.

NOTE 1 The factor used for the reduction of U_P for capacitance values above 1,0 µF maintains 0,5 × $C_N U_P^2$ constant for these capacitance values; C_N is in F.

NOTE 2 Overvoltage categories in association with rated impulse voltage and rated mains voltage are found in IEC 60664-1.

3.2.2 Classification of Y capacitors

Class Y capacitors are further divided into three subclasses, Y1, Y2 and Y4, as shown in Table 2.

Table 2 – Classification of Class Y capacitors

Subclass	Type of insulation bridged	Range of rated voltages	Peak impulse voltage U_P applied before endurance test	
Y1	Double insulation or reinforced insulation	≤500 V	8,0 kV	
Y2	Basic insulation or supplementary insulation	≥150 V ≤500 V	$C_N \leq 1{,}0$ µF	$C_N > 1{,}0$ µF
			5 kV	$U_P = \dfrac{5}{\sqrt{\dfrac{C_N}{10^{-6}\ \text{F}}}}$ kV
Y4	Basic insulation or supplementary insulation	<150 V	2,5 kV	
Y2 capacitors may be substituted by Y1 capacitors of the same or higher U_R.				

NOTE 1 For definitions of basic, supplementary, double, and reinforced insulation, see IEC 61140.

NOTE 2 The factor used for the reduction of U_P for capacitance values above 1,0 µF maintains 0,5 × $C_N U_P^2$ constant for these capacitance values; C_N is in F.

NOTE 3 Overvoltage categories in association with rated impulse voltage and rated mains voltage are found in IEC 60664-1.

One Y1-capacitor may bridge double insulation or reinforced insulation. 3

The enclosure of a Y1-capacitor shall not contain other components.

Assemblies, like Delta by-pass or T-connected by-pass capacitors, may be constructed from Y-capacitors and X-capacitors provided these capacitors fulfil the requirements for the relevant X and Y subclasses.

One Y-capacitor may bridge basic insulation. One Y-capacitor may bridge supplementary insulation. If combined basic and supplementary insulations are bridged by two or more Y2- or Y4-capacitors in series, they shall have the same class and sub-class, the same rated voltage, and the same nominal capacitance value.

4 Preferred ratings and characteristics

4.1 Preferred climatic categories

The values given in detail specifications ~~shall preferably~~ should be selected from this paragraph.

The capacitors covered by this document are classified into climatic categories according to the general rules given in IEC 60068-1:~~1988~~2013, Annex A.

The lower and upper category temperatures and the duration of the damp heat, steady state test shall be chosen from the following:

- lower category temperature: −65 °C, −55 °C, −40 °C, −25 °C and −10 °C;
- upper category temperature: +85 °C, +100 °C, +105 °C, +110°C, +125 °C and +155 °C;
- duration of the damp heat, steady state test: 21 days and 56 days.

The severities for the cold and dry heat tests are the lower and upper category temperatures, respectively.

For guidance on the application of the categories described above, see IEC 60940:2015.

4.2 Preferred values of ratings

4.2.1 Nominal capacitance (C_N)

The preferred values of nominal capacitance are:

1; 1,5; 2,2; 3,3; 4,7; 6,8 and their decimal multiples.

These values conform to the E6 series of preferred values given in IEC 60063.

4.2.2 Tolerance on nominal capacitance

The maximum tolerance on nominal capacitance is ±20 %.

4.2.3 Selection of rated voltages (U_R)

~~The preferred values of rated voltage are 125 V, 250 V, 275 V, 400 V, 440 V, 500 V, 760 V and 1 000 V.~~

The range of rated AC voltages is from 125 V to 1 000 V. 4

The range of rated DC voltages is from 125 V to 1 500 V.

Electromagnetic interference suppression capacitors should be chosen to have a rated voltage equal to, or greater than, the nominal voltage of the supply system to which they are connected. The design of the capacitors ~~should~~ shall take into account the possibility that the voltage of the system ~~may~~ can rise by up to 10 % above the system's nominal voltage. In star connections, the maximum voltage over the capacitors shall be calculated in the worst possible case when the nominal capacitance tolerances of the capacitors used are considered.

4.2.4 Nominal resistance (R_N)

Preferred values of nominal resistance shall be taken from the E6 series of IEC 60063.

4.2.5 Rated temperature

The rated temperature for lead-through capacitors and series RC units shall be not less than +40 °C.

4.2.6 Passive flammability

The preferred category of passive flammability permitted is Category B (see 5.18). If category C is used, it ~~has to~~ shall be agreed between the component supplier and the customer. See 5.18 also for alternative passive flammability testing.

Exemption: for components smaller than 1 750 mm^3, the passive flammability category C is permitted.

NOTE Passive flammability categories better than C ~~may~~ can require flame retardant additives, which ~~may~~ can be considered to cause environmental impact. These categories ~~should be~~ are subject to discussion between manufacturers and customers to find a compromise between safety and environmental requirements.

4.3 Requirements for sleeving, tape, tubing and wire insulation

Sleeving, tape, tubing, and wire insulation used in the components falling under this document shall be rated for the voltage involved and the temperature attained under any condition of actual use. Sleeving, tubing and wire insulation shall have flame retardant rating Class VW1. ~~They~~ Tape shall be flame retardant~~ according to Class VW1~~. 5

If insulated terminals are requested, the preferable colours should be transparent or white.

5 Test and measurement procedures, and performance requirements

5.1 General

This clause supplements the information given in IEC 60384-1:~~2008~~2021, from Clause 4 to Clause 10.

AC tests carried out at a frequency between 50 Hz and 100 Hz are considered valid for any nominal frequency between 50 Hz and 100 Hz. In case of doubt, 50 Hz shall be the reference frequency for measurements.

During handling, testing and inspection, unintended damages to the insulation on component body and leads shall be avoided. The handling instructions as provided by the manufacturer shall be followed. 6

5.2 Visual examination and check of dimensions

5.2.1 General

See IEC 60384-1:~~2008~~2021, 7.1 with the additional details in 5.2.2.

5.2.2 Creepage distances and clearances

Creepage distances and clearances on the outside of the capacitor between live parts of different polarity or between live parts and a metal case shall be not less than the appropriate values given in Table 3.

Table 3 is based on IEC 60664-1, but equipment safety standards IEC 60335-1~~, IEC 60065 and IEC 60950-1~~ and IEC 62368-1 have also been considered. Further information~~ may~~ can be obtained from IEC 60664-1.

Table 3 is generated using the following environmental conditions as main guideline:

Pollution degree 2, altitude ≤ 2 000 m and CTI (Comparative Tracking Index) of materials ≥ 100.

The creepage distances smaller than those in Table 3 can be used, if rules given in IEC 60664-1 for CTI of materials in components allow that. Creepage distance shall always be larger or equal to the clearance distance indicated in this table. Equipment standards~~ may~~ can require larger distances than ones given here.

Compliance shall be checked by measurement in accordance with the rules laid down in IEC 60664-1 for measurements on the outside of the capacitor. Additional requirements~~ may~~ can be necessary, for example for capacitors intended to be used in other environments than pollution degree 2 (e.g. drip-proof and splash-proof capacitors) or for the use of capacitors in altitudes higher than 2 000 m. See IEC 60664-1 for guidance.

Table 3 – Creepage distances and clearances

Points of measurement	Rated voltage (RMS)									
	U_R ≤ 130 V		130 V < U_R ≤ 250 V		250 V < U_R ≤ 500 V		500 V < U_R ≤ 760 V		760 V < U_R ≤ 1 000 V	
	Creepage distance mm	Clearance mm	Creepage distance mm	Clearance mm	Creepage distance mm	Clearance mm	Creepage distance mm	Clearance mm	Creepage distance mm	Clearance mm
Between live parts of different polarity (functional insulation) [a]	2,0	1,5	3,0	2,5	4,0	3,0	6,3	5,5	8,0	5,5
Between live parts and other metal parts over basic insulation [b]	2,0	1,5	4,0	3,0	5,0	4,0	6,3	5,5	8,0	7,5
Between live parts and other metal parts over reinforced insulation [c]	8,0	8,0	8,0	8,0	10,0	8,0	12,6	11,0	16,0	11,0

NOTE The reinforced insulation figures for voltages >500 V are given for information only. In this standard Y1 capacitors are limited to 500 V.

[a] These limits shall be used for measurements between terminals of an X-capacitor.

[b] These limits shall be used for measurements between each terminal and the metal case of an X-capacitor and for measurements between terminals or between each terminal and the metal case of an Y2- or Y4-capacitor.

[c] These limits shall be used for measurements between terminals of an Y1- capacitor (up to 500 V).

Annex J describes different styles of capacitors, and how the creepage and clearance distances are measured for them. Precautions required for handling the capacitors, for example when the leads are bent, are also described. 7

5.3 Electrical tests

5.3.1 Voltage proof

5.3.1.1 General

See IEC 60384-1:~~2008~~2021, 6.2 with the details from 5.3.1.2 to 5.3.1.5.

5.3.1.2 Test circuit for DC tests

Omit the capacitor C_1 if the capacitor under test, or a section of it, is a metallized film or metallized paper capacitor.

The product of R_1 and (C_1 + C_X) shall be less than, or equal to, 1 s and greater than 0,01 s.

R_1 includes the internal resistance of the power supply.

R_2 shall limit the discharge current to a value equal to, or less than, 0,05 A.

5.3.1.3 Test circuit and method for AC tests

When a 50/60 Hz voltage is applied for qualification approval and periodic tests, the voltage shall be supplied from a transformer fed from a variable autotransformer, and the voltage shall be raised from near zero to the test voltage at a rate not exceeding 150 V/s. The test time shall be counted from the time the test voltage is reached. At the end of the test time, the test voltage shall be reduced to near zero and the capacitor discharged through a suitable resistor.

For lot-by-lot and 100 % testing, the voltage shall be applied directly at the full test voltage, but overvoltage peaks should be avoided.

5.3.1.4 Applied voltage

The voltages of Table 4 shall be applied between the respective measuring points shown in IEC 60384-1:~~2008~~2021, Table 3, for a period of 1 min for qualification approval and periodic testing and for a period of not less than 1 s for lot-by-lot quality conformance testing, with the following details:

a) the test in accordance with 2c of IEC 60384-1:~~2008~~2021, Table 3, shall not be carried out;

b) for encapsulated units with a non-metallic case, a voltage proof test such as Test C shall be carried out only for qualification approval tests and periodic tests;

c) the method of applying the test voltage for Test C shall be given in the detail specification. For qualification testing, the foil method given in IEC 60384-1:~~2008~~2021, 6.2.3.4. shall be used, unless otherwise specified in the detail specification;

NOTE This test is applicable only to insulated capacitors in non-metallic case or in insulated metallic case. See IEC 60384-1:~~2008~~2021, 6.6.3.4.

d) for testing during a period between 1 s and 2 s, the voltage of Table 4 shall be increased as indicated in Figure 9;

e) when a capacitor is qualified for DC applications in accordance with Annex H, the test voltage as calculated in accordance with Table H.1 for the voltage proof test A shall be applied for lot-by-lot (100 %) tests and qualification tests, if its value is higher than the value as determined in accordance with Table 4. 8

Attention is drawn to the fact that repetition of the voltage proof test by the user ~~may~~ can damage the capacitor. If repetition of the voltage proof test is made by the user, the applied voltage should not be greater than 66 % of the test voltage specified in Table 4.

Table 4 – Voltage proof

Class	Range of rated voltages	Test A[d]	Test B or Test C
X1 X2	≤ 1 000 V	4,3 U_R (DC) [c]	2 U_R + 1 500 V (AC) with a minimum of 2 000 V (AC) [a]
Y1	≤ 500 V	4 000 V (AC)	4 000 V (AC)
Y2	≥ 150 V ≤ 500 V	U_R + 1 200 V (AC) with a minimum of 1 500 V (AC) [b]	2 U_R + 1 500 V (AC) with a minimum of 2 000 V (AC) [b]
Y4	< 150 V	900 V (AC) [b]	900 V (AC) [b]

[a] For Delta and T-connected capacitor units in accordance with Figure 5b and Figure 5c, the test voltage for terminals to case shall be the appropriate test voltage for the Y-capacitors.

[b] For lot-by-lot tests of Class Y2- and Y4-capacitors, the AC test voltage may be replaced by a DC voltage of 1,5 times the prescribed AC voltage.

[c] The U_R in this DC test is the rated AC voltage value.

[d] For capacitors qualified in accordance with Annex H, see 5.3.1.4 e).

5.3.1.5 Requirements

There shall be no permanent breakdown or flashover during the test period.

NOTE The occurrence of self-healing breakdowns during the application of the test voltages on metalized film capacitors is allowed.

In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). 9

5.3.2 Capacitance

5.3.2.1 General

See IEC 60384-1:~~2008~~2021, 6.3 with the details in 5.3.2.2 and 5.3.2.3.

5.3.2.2 Measuring conditions

The capacitance measured shall be the series equivalent capacitance.

The measuring frequency shall be 1 kHz, but the measuring frequency shall be 1 MHz for ceramic capacitors with C_N < 100 pF (class 2) and C_N ≤ 1 000 pF (class 1).

The measuring temperature shall be in accordance with IEC 60384-1:~~2008~~2021, 5.2.1.

The measuring voltage shall not exceed the rated voltage. For ceramic capacitors, the measuring voltage shall be 1,0 V ± 0,2 V.

As the nominal capacitance of ceramic capacitors, as measured above, is the small-signal capacitance, the manufacturer shall supply the following information for ceramic capacitors:

a) the maximum expected 50/60 Hz current through the capacitor at rated voltage taking into account capacitance tolerance and temperature characteristic (or coefficient) of capacitance;
b) the minimum expected capacitance taking into account the capacitance tolerance and temperature characteristic (or coefficient) of capacitance.

5.3.2.3 Requirements

The capacitance value shall be within the specified tolerance.

5.3.3 Tangent of loss angle

This test is normally required for metallized and ceramic capacitors only.

See IEC 60384-1:~~2008~~2021, 6.4 with the following details:

The measuring frequency shall be 10 kHz for C_N ≤ 1 µF and 1 kHz for C_N > 1 µF. For ceramic capacitors, the measuring frequency shall be 1 kHz, but for capacitors with C_N < 100 pF (class 2) and C_N ≤ 1 000 pF (class 1), the measuring frequency shall be 1 MHz.

5.3.4 Resistance (Equivalent Series Resistance (ESR)) (for RC units only)

The ESR shall be measured in a series equivalent circuit at the following frequency:

100 kHz for $R_N \times C_N < 50$ µs;

1 kHz for $R_N \times C_N \geq 50$ µs

where

R_N is the nominal resistance in ohms, and

C_N is the nominal capacitance in farads.

5.3.5 Insulation resistance

5.3.5.1 General

See IEC 60384-1:~~2008~~2021, 6.1 with the details in 5.3.5.2 and 5.3.5.3.

In lot-by-lot quality conformance testing, the measuring may be interrupted at the time that the value of the insulation resistance exceeds the limits of Table 5 or Table 6, which can be shorter than 60 s.

5.3.5.2 Temperature correction

When ~~prescribed~~ stated in the detail specification, the temperature at which the measurement is made shall be noted. If this temperature differs from 20 °C, a correction shall be made to the measured value by multiplying it by the appropriate correction factor ~~prescribed~~ stated in the sectional specification for the relevant dielectric or that given in the detail specification.

5.3.5.3 Requirements

The insulation resistance shall exceed the values of Table 5 or Table 6, as appropriate.

Table 5 – Insulation resistance – Safety tests only 10

Test A		**Test B or Test C**
When C_N > 0,33 µF RC_N in s	When C_N ≤ 0,33 µF R in MΩ	R in MΩ
2 000 [a, b]	6 000	6 000

- C_N is the nominal capacitance and R the measured insulation resistance.
- Limits more severe and related to the dielectric may be given in the detail specification for performance tests only, where possible by reference to the appropriate IEC publication.
- For capacitors having one termination connected to the case, the insulation resistance limits for Test A should be used.

  For capacitors with a discharge resistor, measurement should be carried out with the discharge resistor disconnected. If the resistor cannot be disconnected without the capacitor being destroyed, the test should be omitted in Group A; and, for qualification approval and periodic tests, the test should be carried out on half of the specimens in the sample, which should consist of capacitors specially made without discharge resistors.

[a] Also for mixed plastic/paper dielectrics.

[b] For capacitors with ester-impregnated paper dielectric, the values of the table shall be replaced respectively by the values 500, 1 500 and 2 000.

Table 6 – Insulation resistance – Safety and performance tests

Dielectric	Test A		Test B or Test C
	When C_N > 0,33 µF RC_N in s	When C_N ≤ 0,33 µF R in MΩ	R in MΩ
Paper [a, b]	2 000	6 000	6 000
Plastic	5 000	15 000	30 000
Ceramic	–	6 000	3 000

~~REMARKS~~

- ~~In the Table 11 and Table 12,~~ C_N is the nominal capacitance and R the measured insulation resistance.
- Limits more severe and related to the dielectric may be given in the detail specification for performance tests only, where possible by reference to the appropriate IEC publication.
- For capacitors having one termination connected to the case, the insulation resistance limits for Test A should be used.
- For capacitors with a discharge resistor, measurement should be carried out with the discharge resistor disconnected. If the resistor cannot be disconnected without the capacitor being destroyed, the test should be omitted in Group A; and, for qualification approval and periodic tests, the test should be carried out on half of the specimens in the sample, which should consist of capacitors specially made without discharge resistors.

[a] Also for mixed plastic/paper dielectrics.

[b] For capacitors with ester-impregnated paper dielectric, the values of the table shall be replaced respectively by the values 500, 1 500 and 2 000.

5.4 Robustness of terminations

See IEC 60384-1:~~2008~~2021, 7.3 with the following details.

The test method and degree of severity to be used shall be specified in the detail specification.

The test for snap-in contacts shall be specified in the detail specification; the test methods and severity shall comply with the applicable clauses of IEC 61210.

The test shall be carefully conducted in accordance with the instructions so that the coating of the capacitor is not broken due to mishandling of the part. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.5 Resistance to soldering heat

5.5.1 General

This test is not applicable to capacitors with insulated leads longer than 10 mm, or to capacitors with terminations not intended to be soldered (such as screw and fast-on terminations).

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

See IEC 60384-1:~~2008~~2021, 9.1 with the details in 5.5.2 and 5.5.3.

5.5.2 Test conditions

There shall be no pre-drying.

5.5.3 Final inspection, measurements, and requirements

The final measurements after this test are the intermediate measurements after the tests of Subgroup 1A and before the remainder of the tests of Group 1. The capacitors shall be visually examined and measured and shall meet the requirements of Table 7.

Table 7 – Resistance to soldering heat – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
Capacitance	5.3.2	The difference between the capacitance measured finally and in Group 0 of Table 14, or Table 15 shall not exceed 5 % [a]
Resistance (if applicable)	5.3.4	$\lvert \Delta R/R \rvert$ ≤ 5 %

[a] For ceramic capacitors, the capacitance difference shall not exceed 10 %.

5.6 Solderability

5.6.1 General

This test is not applicable to capacitors with terminations not intended for soldering (such as screw terminations and snap-in contacts).

See IEC 60384-1:~~2008~~2021, 9.2 with the details in 5.6.2 and 5.6.3.

5.6.2 Test conditions

No ageing is required.

Preferred solders and their solder bath temperature and process time:

- Sn96,5Ag3Cu,5 solder: 245 °C ± 3 °C for (3 ± 0,3) s;
- Sn99,3Cu,7 solder: 250 °C ± 3 °C for (3 ± 0,3) s.

When Method 2 is used, a soldering iron of size A shall be used.

5.6.3 Requirements

See Table K.3.

5.7 Rapid change of temperature

5.7.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

See IEC 60384-1:~~2008~~2021, 8.1 with the following details.

- Number of cycles: 5.
- Duration of exposure at the temperature limits: minimum 30 min.

5.7.2 Final inspection

~~The capacitors shall be visually examined and there shall be no visible damage.~~

In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.8 Vibration

5.8.1 General

See IEC 60384-1:~~2008~~2021, 7.4 with the details in 5.8.2 and 5.8.3.

5.8.2 Test conditions

The following degree of severity of test Fc applies: 0,75 mm displacement or 100 m/s^2, whichever is the lower amplitude, over one of the following frequency ranges: 10 Hz to 55 Hz, 10 Hz to 500 Hz, 10 Hz to 2 000 Hz. The total duration shall be 6 h.

The detail specification shall prescribe the frequency range and shall also prescribe the mounting method to be used. For capacitors with axial leads that are intended to be mounted by the leads, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

5.8.3 Final inspection

~~The capacitors shall be visually examined and there shall be no visible damage.~~

In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.9 Repetitive shock (bump)

5.9.1 General

The detail specification shall state whether the bump or the shock test applies.

See IEC 60384-1:~~2008~~2021, 7.5 with the details in 5.9.2 and 5.9.3.

5.9.2 Test conditions

The following are the preferred severities.

- Total number of bumps: 1 000 or 4 000
- Acceleration: 400 m/s^2
- Pulse duration: 6 ms

The mounting method and the severity shall be specified in the detail specification.

5.9.3 Final inspection, measurements, and requirements

The final measurements after this test are the intermediate measurements after the tests of Subgroup 1B and before the remainder of the tests of Group 1.

The capacitors shall be visually examined and measured and shall meet the following requirements.

- There shall be no visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
- The change of capacitance compared with the value measured in Group 0 of ~~Table 4~~ Table K.3 shall not exceed 5 %, except for ceramic capacitors for which it shall not exceed 10 %.
- The value of tan δ shall not exceed the limit ~~prescribed~~ stated in the detail specification.
- The change of resistance (if applicable) shall not exceed the limit in Table 9.

When preconditioning is performed, initial measurements for reference shall be carried out after preconditioning.

5.10 Shock

5.10.1 General

The detail specification shall state whether the bump or the shock test applies.

See IEC 60384-1:~~2008~~2021, 7.6 with the details in 5.10.2 and 5.10.3.

5.10.2 Test conditions

The severities in Table 8 are preferred.

Pulse-shape: half-sine wave

Table 8 – Shock test preferred severities

Peak acceleration m/s^2	**Corresponding duration of the pulse** ms
500	11
1 000	6

The mounting method, the severity, and the number of shocks along each axis shall be specified in the detail specification.

5.10.3 Final inspection, measurements, and requirements

The final measurements after this test are the intermediate measurements after the tests of Subgroup 1B and before the remainder of the tests of Group 1.

The capacitors shall be visually examined and measured and shall meet the following requirements.

- There shall be no visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

- The change of capacitance compared with the value measured in Group 0 of Table K.3 shall not exceed 5 %, except for ceramic capacitors for which it shall not exceed 10 %.
- The value of tan δ shall not exceed the limit ~~prescribed~~ stated in the detail specification.
- The change of resistance (if applicable) shall not exceed the limit in Table 9.

When preconditioning is performed, initial measurements for reference shall be carried out after preconditioning.

5.11 Container sealing

5.11.1 General

This test is applicable only if prescribed in the detail specification.

See IEC 60384-1:~~2008~~2021, 7.9 with the details in 5.11.2 and 5.11.3.

5.11.2 Test conditions

The capacitors shall be subjected to either Test Qc or to Test Qd of IEC 60068-2-17, as appropriate. Unless otherwise specified in the detail specification, Method 1 shall be used when Test Qc is employed.

5.11.3 Requirements

During or after the test, as applicable, there shall be no evidence of leakage.

5.12 Climatic sequence

5.12.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

See IEC 60384-1:~~2008~~2021, 8.2 with the details from 5.12.2 to 5.12.7.

5.12.2 Initial measurements

The initial measurements for the climatic sequence are the measurements carried out in 5.5.3, 5.9.3 or 5.10.3 as appropriate.

5.12.3 Dry heat

See IEC 60384-1:~~2008~~2021, 8.2.3 with the following details.

No measurements are required at the upper category temperature.

5.12.4 Damp heat, cyclic, test Db, first cycle

See IEC 60384-1:~~2008~~2021, 8.2.4.

5.12.5 Cold

See IEC 60384-1:~~2008~~2021, 8.2.5 with the following details.

No measurements are required at the lower category temperature.

5.12.6 Damp heat, cyclic, test Db, remaining cycles

See IEC 60384-1:~~2008~~2021, 8.2.7.

5.12.7 Final inspection, measurements, and requirements

See IEC 60384-1:~~2008~~2021, 8.2.8 with the following details.

Recovery shall be for 24 h ± 2 h under standard atmospheric conditions for testing.

After recovery, the capacitors shall be visually examined and measured and shall meet the requirements of Table 9.

Table 9 – Climatic sequence – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	The final capacitance value shall be within 5 %[a] of the value measured in 5.5.3, 5.9.3 or 5.10.3 as applicable
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,008 for $C_N \leq 1$ µF 0,005 for $C_N > 1$ µF
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage given in Table 4 No permanent breakdown or flashover is permitted
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors, the capacitance difference shall not exceed 10 %.

5.13 Damp heat, steady state (DHSS)

5.13.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

~~Requirements for capacitors used in high humidity applications are contained in Annex I.~~

Annex I describes specific humidity robustness grades, tests, and requirements for applications, where high stability under high humidity operating conditions is required. A sample tested to comply to one of the robustness grades of Annex I fulfils the requirements of the second half of the sample described in 5.13.3 (DHSS with voltage applied), and the test results are valid for approval testing in accordance with 8.4, Annex F or Annex K. 11

See IEC 60384-1:~~2008~~2021, 8.3 with the details from 5.13.2 to 5.13.4.

5.13.2 Initial measurements

Initial measurements have been carried out in Group 0 of Table 14 or Table 15.

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

5.13.3 Test conditions

The sample shall be divided to two parts of equal size.

The first half of the sample shall be tested without voltage applied with following preferred severities:

- Temperature: 40 °C ± 2 °C;
- Relative humidity: (93 ± 3) %;
- Duration: 21 days or 56 days, in line with the climatic category of the capacitor.

~~When the test is made on ceramic capacitors, half of the sample shall have the rated voltage applied and the other half shall have no voltage applied.~~

~~For all other capacitors, no voltage shall be applied during the test.~~

The other half of the sample shall be tested with rated AC voltage applied in the following conditions: **12**

- Temperature: 40 °C ± 2 °C;
- Relative humidity: (93 ± 3) %;
- Duration: 21 days.

5.13.4 Final inspection, measurements, and requirements

Recovery shall be for 1 h to 2 h under standard atmospheric conditions for testing.

After recovery, the capacitors tested without voltage shall be visually examined and measured and shall meet the requirements of Table 10.

After recovery, the capacitors tested with voltage shall be visually examined and measured and shall meet the requirements of Table 11. The electrical requirements of Table 11 are identical to those of Table I.1.

Table 10 – Damp heat, steady state – Requirements for samples tested without voltage applied

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	The final capacitance value shall be within 5 %[a] of the value measured in Group 0 of Table 16 or ~~4~~ Table K.3, as applicable
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,008 for $C_N \leq 1$ µF 0,005 for $C_N > 1$ µF
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage as in Table 4 No permanent breakdown or flashover is permitted
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors the capacitance difference shall not exceed 15 %.

Table 11 – Damp heat, steady state – Requirements for samples tested with voltage applied 13

Measurement	Measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	Metalized capacitors: $\lvert \Delta C \rvert \leq 10$ % Ceramic capacitors: $\lvert \Delta C \rvert \leq 15$ %
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,024 for $C_N \leq 1$ µF [a] 0,015 for $C_N > 1$ µF [a]
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage as in Table 4
Insulation resistance	5.3.5	> 50 % of the applicable limits of Table 5 or Table 6, or minimum 200 MΩ, whichever is higher

The change of capacitance value depends on technology, and, as is for example the case for ceramic capacitors, can be reversible. Thus, the requirements are different.

[a] For certain applications, smaller values for the increase tan δ can be required.

5.13.5 Sample size summary for humidity tests 14

Table 12 shows sample sizes for humidity tests in accordance with 5.13, Annex H and Annex I.

Table 12 – Sample sizes for humidity tests

DHSS Test group	Without voltage	U_R AC applied	U_R DC applied
5.13	6	6[b]	
Annex H, Table H.1	+ 0	+ 0	+ 6[a]
Annex I, Grade (I), (II), (III)	+ 0	10	+ 6[a]

NOTE The + sign in front of the numbers means an additional sample to the samples of 5.13.

[a] Additional sample if the capacitors are also specified for U_R DC exceeding U_R AC (RMS)

[b] See 5.13.1

5.14 Impulse voltage

5.14.1 General

This test is to be carried out as a sequence with the endurance test described in 5.15.

5.14.2 Initial measurements

Initial measurements have been made in Group 0 of Table 17 or Table K.3.

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

5.14.3 Test conditions

Each individual capacitor shall be subjected to a maximum of 24 impulses of the same polarity. The time between impulses shall be not less than 10 s. The peak value of the voltage impulse shall be as given in Table 1 and Table 2.

The rise time, $t_{r,}$ is defined as $t_r = (t_{90} - t_{30}) \times 1{,}67$. Time t_r is the front time T_1 defined in IEC 60060-1:2010, 7.1.18.

The decay time t_d is the same as time to half value T_2 defined in IEC 60060-1:2010, 7.1.22.

The waveform will be determined by the test circuit parameters. Details of the test circuit are given in Annex A.

Before use, the functioning of the circuit shall be checked using C_X values of 0,01 μF and 0,1 μF and the values for the other circuit elements as given in Table A.1. The rise time t_r and decay time t_d shall be within 0 % + 50 % of the values given in Table A.2. The capacitors C_X used for this check should not be high-permittivity ceramic.

If the waveform from the check shows a damped oscillation, the peak-to-peak value of this oscillation, U_{pp}, shall be not greater than 10 % of the peak voltage of the impulse U_{CR} as shown in Figure 6.

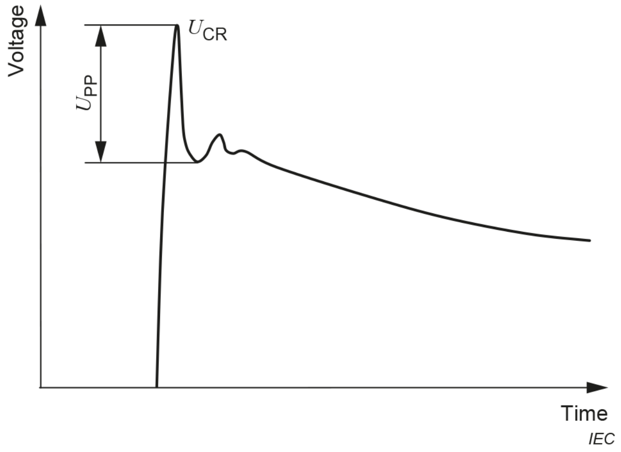


Figure 6 – Impulse wave form

5.14.4 Requirements

There shall be no permanent breakdown or flashover.

If any three successive impulses are shown by the oscilloscope monitor to have had a waveform indicating that no self-healing breakdowns or flashovers have taken place in the capacitor, then no further impulses shall be applied, and the capacitor shall be counted as conforming.

If all 24 impulses have been applied to the capacitor and 3 or more of them are of a waveform indicating that no self-healing breakdowns or flashovers have occurred, then the capacitor shall be counted as conforming, but, if fewer than three impulses are of the required waveform, then the capacitor shall be counted as a nonconforming item.

5.15 Endurance

5.15.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

The endurance test shall be started within one week of the completion of the impulse voltage test. See IEC 60384-1:~~2008~~2021, 8.5 with the details from 5.15.2 to 5.15.9.

5.15.2 Test conditions

The capacitors shall be placed in the test chamber in such a manner that no capacitor is within 25 mm of any other capacitor.

However, there is an exception, when the width or diameter of the capacitor is less than 25 mm, then the distance between the capacitors may be reduced to the value of this width or diameter, provided that this causes no extra heating of the capacitors. If in doubt, the 25 mm spacing shall be used.

The capacitors shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from exceeding ±3 °C of the specified temperature at any point where capacitors are placed.

For non-self-healing capacitors, a 1 A fuse or larger, if the capacitance value under test so requires, shall be connected in the supply circuit, and shall not rupture during the test.

~~NOTE~~ For self-healing capacitors, a fuse or other device of suitable sensitivity may be connected in the circuit of each capacitor to indicate if a failure occurs.

5.15.3 Sampling

The sample for the endurance test shall be divided, if necessary, into two or three parts according to the numbers given in Table 15, Table K.1, Table 17, or Table K.3, so that separate tests ~~may~~ can be carried out on the X-capacitors, the Y-capacitors, and the lead-through arrangements.

For example, when testing delta capacitor units (see 3.1.9), 12 capacitor units shall be tested according to 5.15.5 and another 12 units according to 5.15.6. When testing a Class Y lead-through capacitor (see 3.1.8), 12 capacitors shall be tested in accordance with 5.15.6 and six units in accordance with 5.15.7.

5.15.4 Initial measurements

Initial measurements have been carried out in 5.14.2.

5.15.5 Endurance for Class X capacitors and RC units containing Class X capacitors

For multi-section capacitors, all X-sections shall be tested in parallel, if necessary, by shorting out any Y-sections. For T-connected capacitors (see 3.1.9), the test shall be carried out between the terminals normally connected to line and neutral.

The capacitors and RC units, for which no rated temperature is given, shall be submitted to an endurance test of 1 000 h at upper category temperature at a voltage of 1,25 U_R, except that once every hour, the voltage shall be increased to voltage U_S RMS for 0,1 s, where $U_S = 1{,}5 \times U_R$ or 1 000 V RMS, whichever is higher. Each of these voltages shall be applied to each capacitor individually through a resistor of 47 Ω, with a tolerance of ±5 %. The suitable circuit is shown in Annex B.

~~NOTE~~ The value of this resistor is chosen to simulate the high-frequency impedance of the supply mains. For capacitors with capacitance value above 10 µF, the dissipated power in the resistor becomes large. With increasing capacitance values the dissipated power may rise to unpractical level. In this kind of situation, safety test houses may allow a lower resistance value of 5 % of the reactance value of the test capacitor C_x to be used.

RC units, for which a rated temperature is given, shall be mounted in the manner specified by the manufacturer, and the oven shall be stabilized at the rated temperature without voltage applied to the capacitors. The voltage shall then be switched on and the time counted from this moment.

After thermal stability due to internal heating of the resistor has been re-established, the case temperature of one of the capacitors shall be measured. It shall not exceed the upper category temperature.

The test circuit should be designed so that voltage transients and current surges are avoided during switching. This may be achieved by discharging the capacitor before switching to the new voltage provided that the total time taken to change over to U_S RMS and back does not exceed 30 s.

5.15.6 Endurance for Class Y capacitors and RC units containing Class Y capacitors

For multi-section capacitors, all Y-sections shall be tested in parallel, if necessary, by shorting out any X-sections. For T-connected capacitors (see 3.1.9), the terminals normally connected to line and neutral shall be shorted and the test shall be carried out between them, and the terminal normally connected to earth.

The capacitors shall be submitted to an endurance test of 1 000 h at an upper category temperature at a voltage of 1,7 U_R, except that once every hour the voltage shall be increased to voltage U_S RMS for 0,1 s, where U_S = ~~1,5 × U_R or~~ 1 000 V RMS~~, whichever is higher~~. Each of these voltages shall be applied to each capacitor individually through a resistor of 47 Ω with a tolerance of ±5 %. The test circuit is shown in Annex B.

The test circuit should be designed so that voltage transients and current surges are avoided during switching. This may be achieved by discharging the capacitor before switching to the new voltage provided that the total time taken to change over the U_S RMS and back does not exceed 30 s.

5.15.7 Endurance for the lead-through arrangements

In addition to the endurance tests of the capacitors in accordance with 5.15.5 and 5.15.6, the current-carrying capacity of the lead-through arrangements shall be tested. All the lead-through wires shall be connected in series and the capacitors submitted to an endurance test of 1 000 h with a current of 1,1 I_R passing through the lead-through wires. During this test, no voltage is applied to the capacitor dielectric.

The capacitors shall be mounted in the manner specified by the manufacturer, and the oven shall be stabilized at the rated temperature without current passing through the capacitors. The current shall then be switched on and the time counted from this moment.

After thermal stability has been re-established, the case temperature of one of the capacitors shall be measured. It shall not exceed the upper category temperature.

5.15.8 Test conditions – Combined voltage/current tests

For some types of capacitors, such as coaxial lead-through capacitors, it is possible without difficulty to apply both test voltage and current to the capacitor at the same time. If prescribed in the detail specification, a combined endurance test of 1 000 h may be carried out instead of the tests of 5.15.5 (or 5.15.6) and 5.15.7 by using the number of specimens appropriate for the test of 5.15.5 (or 5.15.6) and 1,1 times the rated current flowing through the lead-through arrangements.

The case temperature of one of the capacitors shall be measured as in 5.15.7. It shall not exceed the upper category temperature.

5.15.9 Final inspection, measurements, and requirements

The capacitors shall be visually examined and measured in the order given in Table 13.

Table 13 – Endurance – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
Capacitance	5.3.2	The final capacitance value shall be within 10 % [a] of the value in Group 0 of Table 15 or Table K.1 as applicable
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,008 for $C_N \leq 1$ µF 0,005 for $C_N > 1$ µF
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 10$ %
Voltage proof	5.3.1	Test voltage as in Table 4 No permanent breakdown or flashover is permitted
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors the capacitance difference shall not exceed 20 %.

5.16 Charge and discharge

5.16.1 General

This test is applicable only to metallized capacitors, ceramic capacitors and RC units using such capacitors.

See IEC 60384-1:~~2008~~2021, 6.11 with the details from 5.16.2 to 5.16.4.

5.16.2 Initial measurements

Initial measurements have been made in Group 0 of Table 15 or Table K.1. In addition, except for RC units, tan δ shall be measured in accordance with IEC 60384-1:~~2008~~2021, 6.4 with the following details.

C_N:	≤ 1 µF	C_N:	>1 µF
Frequency:	10 kHz	Frequency:	1 kHz
Voltage:	1 V RMS. max.	Peak voltage:	≤ 3 % of rated voltage

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

5.16.3 Test conditions

The capacitors shall be subjected to 10 000 cycles of charge and discharge at the rate of approximately one operation per second.

Each cycle shall consist of charging and discharging the capacitor. For AC capacitors, the test voltage shall be $\sqrt{2} \times U_R$ and for DC capacitors the test voltage shall be U_R.

Each capacitor shall be individually charged by applying the test voltage through a resistor with the value

$$R = \frac{220 \times 10^{-6}}{C_N} \ \Omega$$

or the value required to limit the charge current to 1 A (or to the higher current value given in the detail specification), whichever resistance value is the greater.

Each capacitor shall be individually discharged through a resistor of such a value that the maximum rate of change of voltage ($\mathrm{d}U/\mathrm{d}t$) shall be approximately 100 V/µs.

For RC units, if it is impossible to achieve a discharge rate of 100 V/µs, the RC unit shall be discharged through a short circuit.

The circuit is given in Annex C.

In Annex E (Pulse test circuits), alternative possibilities for a test circuit are given for information.

5.16.4 Final measurements and requirements

The capacitor shall be measured and shall meet the requirements of Table 14.

Table 14 – Charge and discharge – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Capacitance	5.3.2	The final capacitance value shall be within 10 % [a] of the value in Group 0 of Table 15 or Table K.1, as applicable
Tan δ for $C_N \leq 1$ µF $f = 10$ kHz (if applicable)	5.16.2	The increase of tan δ over the value measured in 5.16.2 shall not exceed 80×10^{-4}
Tan δ for $C_N > 1$ µF $f = 1$ kHz (if applicable)	5.16.2	The increase of tan δ over the value measured in 5.16.2 shall not exceed 50×10^{-4}
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 10$ %
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors, the capacitance difference shall not exceed 20 %.

5.17 Radiofrequency characteristics

The detail specification may prescribe measuring methods and requirements for one or more of the following radiofrequency characteristics:

- the main resonant frequency of the capacitor;
- insertion loss (the methods of CISPR 17 shall be used where possible);
- resistance at resonant frequency;
- impedance of the capacitor;
- inductance of the capacitor.

5.18 Passive flammability test

5.18.1 Testing according to IEC 60384-1

5.18.1.1 General

See IEC 60384-1:~~2008~~2021, 10.1 with the following details.

No test according to Group 0 and no preconditioning are required.

The test shall be carried out on 6 to 18 specimens, depending on the number of case sizes tested. The smallest, a medium (in the case of more than 4 case sizes in the range to be qualified), and the largest case size in the range to be qualified, shall be tested. For each case size, 3 specimens, each of the highest and lowest capacitance values of the range to be qualified, shall be tested.

The flame shall be applied for the period of time specified in the generic specification corresponding to the volume of the specimen and the category of flammability specified in the detail specification.

The preferred category is category B. If category C is used, it ~~has to~~ shall be agreed between the component supplier and the customer.

Exemption: for components smaller than 1 750 mm^3, passive flammability category C is permitted.

Passive flammability categories better than C may require flame retardant additives, which ~~may~~ can be considered to cause environmental impact. These categories should be subject to discussion between manufacturers and customers to find a compromise between safety and environmental requirements.

For surface mount capacitors consisting of ceramic and metal, only the passive flammability test can be omitted.

5.18.1.2 Requirements

The burning time specified in the generic specification shall not be exceeded by any specimen. The tissue paper shall not ignite. No electrical measurements are required.

5.18.2 Alternative passive flammability test

5.18.2.1 General

In situations where the components do not have passive flammability category B, or where category C has not been agreed upon, and the volume of the capacitor is greater than 1 750 mm^3, or when the polymeric enclosure materials are not classified V-0 in accordance with IEC 60695-11-10, the following alternative test method can be used.

Three samples of the component are to be subject to three 15 s applications of a test flame, the period between the applications of the flame being 15 s. The component shall not continue to flame for more than 15 s after the first and second applications, and not more than 60 s after the third application.

5.18.2.2 Requirements for the test set-up

For the test, a supply of gas having a heating value of approximately 37,6 MJ/m^3 (1 000 Btu/ft^3) at normal pressure and a 9,5 mm (3/8 inch) diameter Tirril burner are to be used. The test flame is to be 19 mm (3/4 inch) high with the air ports of the burner closed.

5.18.2.3 Requirements for the conduction of the test

Each component is to be mounted in a position that is most conductive to the ignition of the component and that is permitted by the physical construction of the component. The tip of the test flame is to be applied at any location on the body of each component. No electrical measurements are required.

5.19 Active flammability test

5.19.1 Test condition

~~This test is not applicable to Y1 capacitors.~~

The active flammability test for Y1 capacitors is omitted because the current test set-ups can create excessive over-voltage on a Y1 capacitor. **15**

The sample of 24 specimens shall contain equal numbers of specimen of the highest, the lowest and an intermediate capacitance value in the range to be qualified. Where there are only two capacitance values in the range, 12 of each value shall be tested; where only 1 capacitance value is involved, 24 capacitors of this value shall be tested.

The specimens shall be individually wrapped in at least 1, but not more than 2, complete layers of cheesecloth. The cheesecloth shall be untreated pure cotton cloth with a mass of 20 g/m^2 to 60 g/m^2 and having a count of between 22 × 27 and 45 × 34 that has been pre-conditioned under standard atmospheric conditions for testing for 24 h.

Each test capacitor shall be mounted by its leads. The free length of the leads ~~shall preferably~~ should be at least 25 mm.

Using the test circuit of Figure 7 with the following details:

$U\sim$ = $U_R \pm 5$ %

U_i = 5 kV $^{+7}_{0}$ % for capacitors of Class Y2

= 4 kV $^{+7}_{0}$ % for capacitors of Class X1

= 2,5 kV $^{+7}_{0}$ % for capacitors of Class X2 and Y4

Each sample shall be subjected to 20 discharges from a tank capacitor, charged to a voltage that, when discharged, places U_i across the capacitor under test. The interval between successive discharges shall be 5 $^{+1}_{0}$ s. See Figure 8 for the intended wave form.

Throughout the test, the $U\sim$ shall be applied across the capacitor under test and shall be maintained for 120 $^{+10}_{0}$ s after the last discharge, unless a blown fuse causes an open circuit.

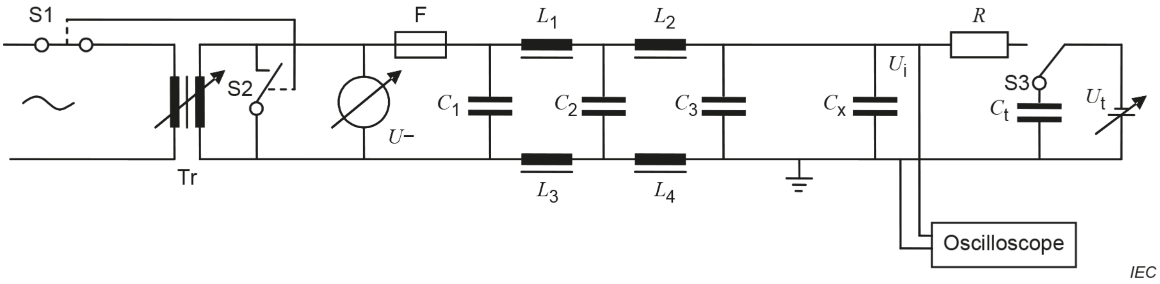


Figure 7 – Typical circuit for pulse loading of capacitors under AC voltage

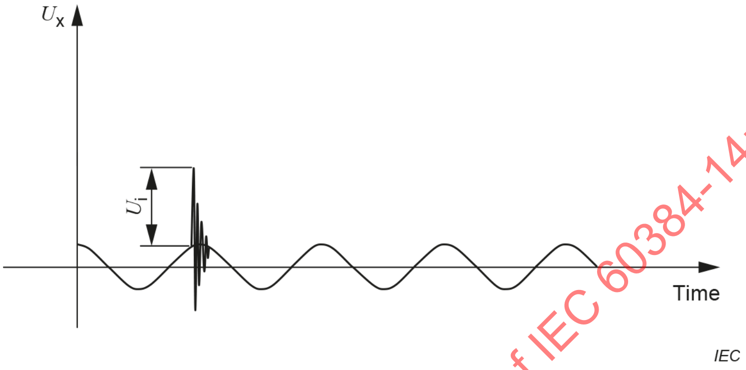


Figure 8 – Fundamental AC wave with randomly, not synchronized, superimposed high-voltage pulse

Tr = isolation transformer for blocking with secondary voltage of U~, and a sufficient capacity to supply 16 A to the test circuit at a voltage of ≥ 0,9 × U~;

C_1, C_2 = filter capacitor 1 µF ± 10 %;

L_1 .. L_4 = rod core choke 1,5 mH ± 20 %, 16 A;

C_3 = capacitor 0,033 µF ± 5 %;

R = 5 Ω ± 2 % for C_x ≥ 1 µF;

= 10 Ω ± 2 % for 0,22 µF ≤ C_x < 1 µF;

= 40 Ω ± 2 % for 0,068 µF ≤ C_x < 0,22 µF;

= 100 Ω ± 2 % for C_x < 0,068 µF;

C_x = capacitor under test;

U_t = voltage to which the tank capacitor C_t is charged;

C_t = tank capacitor is 3 µF ± 5 % up to C_x = 1 µF, and ≥3 × C_x for C_x > 1 µF. The recommended value is 3 × C_x, but it is allowed to use a reasonably higher value in order to standardize the test equipment;

F = slow-blow fuse, rated 16 A.

NOTE C_1, C_2 and L_1 ... L_4 comprise a mains protection filter; other configurations for these filters are permitted.

C_3 and C_t should have a suitable voltage compared to the required U_t during test.

5.19.2 Adjustment of U_i

The AC voltage shall be switched off by S_1 and the secondary winding of the transformer shall be short-circuited by S_2. A set-up capacitor of capacitance C_x with a tolerance of ± 5 % shall be connected in the C_x position. U_t shall then be adjusted so that the required peak voltage U_i appears across capacitor C_x, as demonstrated by the oscilloscope. The test shall then be conducted on the capacitors under test using this setting of U_t.

5.19.3 Requirements

The cheesecloth around the capacitor shall not burn with a flame. No electrical measurements are required.

5.20 Component solvent resistance (if applicable)

See IEC 60384-1:~~2008~~2021, 9.4 with the following details.

The detail specification shall specify whether tests are required using solvents additional to those specified in the generic specification.

The requirements shall be specified in the detail specification.

5.21 Solvent resistance of the marking

See IEC 60384-1:~~2008~~2021, 9.5 with the following details.

The detail specification shall specify whether tests are required using solvents additional to those specified in the generic specification.

The marking shall be legible.

6 Marking

6.1 General

See IEC 60384-1:~~2008~~2021, 4.3 with the following details.

6.2 Information for marking

The information given in the marking is normally selected from the following list. The relative importance of each item is indicated by its position in the list:

a) manufacturer's name or trademark;
b) manufacturer's type designation or the type designation given in the detail specification;
c) capacitor class and subclass;
d) recognized approval mark;
e) nominal capacitance(s) and nominal resistance;
f) rated voltage and nature of supply (alternating voltage may be indicated by the symbol ~ (IEC 60417-5032:2002) and direct voltage by the symbol ⎓ (IEC 60417-5031:2002) or —, also AC and DC respectively for alternating voltage and direct voltage can be used;
g) the method of connection, if necessary;
h) rated current of the conductor (in the case of a lead-through capacitor);
i) tolerance on ~~rated~~ nominal capacitance if different from ±20 %;

j) climatic category, followed by a letter indicating passive flammability category;

k) rated temperature;

l) year and month (or week) of manufacture;

m) reference to the detail specification.

6.3 Marking of capacitors

The capacitor shall be clearly marked with a), b) and c) and also d), e) and f) in 6.2, if these are not implied by b) in 6.2, and as many of the remaining items as are considered necessary by the manufacturer. The marking shall be sufficient to enable clear identification of the component.

NOTE For surface mount components, see Annex F.

It is recommended that a caution mark be printed on the printed circuit board where a safety component is mounted. The caution mark shall be ISO 7000-0434:2004. The mark is in the form of an upright equilateral triangle containing an exclamation mark.

This caution mark is referred to in ~~IEC 60065:2001, 5.3~~ IEC 62368-1:2018, Annex F (Clause F.5 and Table F.2). Any duplication of information in the marking on the capacitor should be avoided.

6.4 Marking of packaging

The package containing the capacitor(s) shall be clearly marked with all the information listed above. National approvals may be indicated by lettering as an alternative to the approval mark.

6.5 Additional marking

Any additional marking shall be applied in such a way that no confusion can arise.

7 Information to be given in a detail specification

7.1 General

Detail specifications shall be derived from the relevant blank detail specification.

Detail specifications shall not specify requirements inferior to those of the generic, sectional, or blank detail specification. When more severe requirements are included, they shall be listed in the relevant clause of the detail specification, and indicated in the test schedules, for example, by an asterisk.

The information in 7.2 to 7.4 shall be given in each detail specification and the values quoted ~~shall preferably~~ should be selected from the appropriate clause of this sectional specification.

Requirements for safety approved AC capacitors to be used in DC applications are found in Annex H.

~~NOTE~~ The information given in 7.2 may, for convenience, be presented in tabular form.

7.2 Outline drawing and dimensions

There shall be an illustration of the capacitor as an aid to easy recognition and for comparison of the capacitor with others. Dimensions and their associated tolerances, which affect interchangeability and mounting, shall be given in the detail specification. All dimensions ~~shall preferably~~ should be stated in millimetres; however, when the original dimensions are given in inches, the converted metric dimensions in millimetres shall be added.

Normally, the numerical values shall be given for the length, width and height of the body and the wire spacing, or for cylindrical types, the body diameter and the length and diameter of the terminations. When necessary, for example when several capacitance values/voltage ranges are covered by a detail specification, their dimensions and their associated tolerances shall be placed in a table below the drawing.

When the configuration is other than that described above, the detail specification shall state such dimensional information as will adequately describe the capacitor. When the capacitor is not designed for use on printed boards, this shall be clearly stated in the detail specification.

7.3 Mounting

The detail specification shall specify the method of mounting to be applied for normal use and for the application of the vibration, bump, or shock tests. The capacitors shall be mounted by their normal means. The design of the capacitor may be such that special mounting fixtures are required for its use. In this case, the detail specification shall describe the mounting fixtures and they shall be used in the application of the vibration, bump, or shock tests.

If recommendations for mounting for "normal" use are made, they should be included in the detail specification under "Additional information (not for inspection purposes)". If recommendations are included, a warning can be given that the full vibration, bump and shock performance may not be available if mounting methods other than those specified in 1.1 of the detail specification are used.

7.4 Ratings and characteristics

7.4.1 General

The ratings and characteristics shall be in accordance with the relevant clauses of this specification, together with information in 7.4.2 to 7.4.4.

7.4.2 Nominal capacitance range

The preferred range of capacitance values should follow 4.2.1 of this document.

When products approved to the detail specification have different ranges, the following statement should be added: "The range of values available in each voltage range is given in the register of approvals, available for example on the website www.iecq.org".

7.4.3 Nominal resistance range (if applicable)

The preferred range of resistance values should follow 4.2.4 of this document.

7.4.4 Particular characteristics

Additional characteristics may be listed, when they are considered necessary to specify the component adequately for design and application purposes.

~~1.4.4 Marking~~

~~The detail specification shall specify the content of the marking on the capacitor and on the package. See also 1.6 of this standard.~~

8 Assessment procedures

8.1 Primary stage of manufacture

For wound capacitors, the primary stage of manufacture is the winding of the capacitor element. For single-layer ceramic capacitors, it is the metallization of the dielectric to form the electrodes.

For fixed multilayer ceramic capacitors, it is the first common firing of the dielectric-electrode assembly. For other types of capacitors, it shall be the same as that given in the sectional specification for the dielectric used.

8.2 Structurally similar components

Capacitors considered as being structurally similar are capacitors produced with essentially the same processes and materials, though they ~~may~~ can be of different case sizes and capacitance values, but of the same class and rated voltage.

8.3 Certified records of released lots

The information required in IEC 60384-1:~~2008~~2016, Q.1.5, shall be made available when prescribed in the detail specification and when requested by a customer. After the endurance test, the parameters for which variable information is required are capacitance change, resistance change (for RC units), tan δ and insulation resistance.

8.4 Approval testing

8.4.1 Safety tests only qualification approval

Table 15 and Table 17 form a schedule limited to tests concerning safety only requirements. The schedule to be used for safety tests only approval will be ~~on the basis~~ because of fixed sample sizes as given in 8.4.3 and Table 15 of this document. Prior to the approval testing being carried out, it is necessary to submit to the certification body a declaration of design (see Annex D) registering essential data and basic design details of the capacitors for which approval is sought.

8.4.2 Qualification approval based on safety and performance testing

See Annex K. **16**

8.4.3 Qualification approval based on the fixed sample size procedure

8.4.3.1 Sampling

Capacitors of each technology, rated voltage, class, and subclass shall be separately qualified. The total number of capacitors of each rated voltage in each group is given in Table 15 and Table 16 or Table K.1 and Table K.2. For multi-section capacitors containing sections of different classes and for lead-through capacitors, larger numbers are required as indicated.

The sample shall contain equal numbers of specimens of the highest and lowest capacitance values in the range to be qualified, except for the passive flammability test of 5.18 and the active flammability test of 5.19. For the passive flammability test, the rules of sampling in 5.18, footnote d to Table 15 and footnote h to Table 16 shall be followed. For the active flammability test, the rules of sampling in 5.19 shall be followed. For RC units, the sample of highest capacitance values and the sample of the lowest capacitance values shall contain each, as nearly as possible, an equal number of resistors of the highest and lowest resistance value in the range to be qualified. Where only one capacitance value is involved, the total number of capacitors as stated in Table 15 and Table 16, or Table K.1 and Table K.2 shall be tested.

Spare specimens are permitted as follows:

1) one per capacitance value which may be used to replace the permitted nonconforming item in Group 0;
2) the remainder of the spare specimens may be required, if it is necessary, to repeat any test according to the provisions of footnote a of either Table 15 or Table K.1.

The numbers given in Group 0 assume that all subgroups are applicable. If this is not so, the numbers may be reduced accordingly.

When additional groups are introduced into the qualification approval test schedule, the number of specimens required for Group 0 shall be increased by the same number as that required for the additional groups.

Table 15 and Table 16 or Table K.1 and Table K.2 give the number of specimens to be tested in each group or subgroup together with the permissible number of nonconforming items in each case.

Where a range of ceramic capacitors to be qualified consists of different temperature characteristics (or coefficients) or the range of capacitors employs significantly different materials, the samples for Groups 2, 3 and 7 shall contain the specified quantity of specimens for each temperature characteristics (or coefficients) or dielectric material group as specified below:

Group A: Materials with ~~dielectric constant~~ relative permittivity $\varepsilon_r < 500$

Group B: Materials with ~~dielectric constant~~ relative permittivity $500 \le \varepsilon_r < 5\,000$

Group C: Materials with ~~dielectric constant~~ relative permittivity $\varepsilon_r \ge 5\,000$

8.4.3.2 Tests

One of the complete series of tests indicated in Table 15 and Table 17 or Table K.1 and Table K.3 is required for the approval of capacitors of a single rated voltage covered by one detail specification. The tests of each group shall be carried out in the order given.

For surface mount capacitors, the specific requirements of Annex F and Table F.1 shall be followed.

The whole sample shall be subjected to the tests of Group 0 and then subdivided for the other groups.

A specimen found to be a nonconforming item during the tests of Group 0 shall not be used for the other groups.

"One nonconforming item" is counted when a capacitor has not satisfied the whole or part of the tests of a group.

Approval is granted when the number of nonconforming is zero.

Fixed sample size test schedules for safety tests only are given in Table 15, Table 16, and Table 17, for safety and performance qualification approval in Table K.1, Table K.2 and Table K.3. Table 15, Table 16, or Table 17 include the details for the sampling and permissible nonconforming items for the different tests or groups of tests. Table 17 or Table K.3, together with the details of test contained in Clause 5, give a complete summary of test conditions and performance requirements, and indicate where, for test methods or conditions of test, a choice shall be made in the detail specification.

The conditions of test and performance requirements for the fixed sample size schedule should be identical to those prescribed in the detail specification for the quality conformance inspection.

Table 15 – Sampling plan – Tests concerning safety requirements only

Group	Test	Subclause of this document	Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass Per group
0	Visual examination	5.2	~~28~~ 30 + 12[b]+	0
	Capacitance	5.3.2	6[c] +	
	Resistance	5.3.4	6 to18[d]	
	Voltage proof	5.3.1	+24	
	Insulation resistance	5.3.5		
	Tangent of loss angle (metallized film and paper capacitors only) 17	5.3.3		
	Spares		14 + 6[c]	
1A	Creepage distances and clearances	5.2.2	6	0[a]
	Robustness of terminations	5.4		
	Resistance to soldering heat	5.5		
	Solvent resistance of the marking	5.21		
2	Damp heat, steady state	5.13	12	0[a]
3	Impulse voltage	5.14		0[a]
	Endurance	5.15		
	Class X and RC units	5.15.4	12[b]	
	Class Y and RC units	5.15.5	12[b]	
	Lead-through[e]	5.15.6	6[c]	
6	Passive flammability	5.18	6 to 18[d]	0
7	Active flammability	5.19	24	0

Tests in Group 0 can be carried out in any practical order, except for ceramic capacitors whose capacitance value shall be measured first.

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] If multi-section capacitors consisting of X- and Y-capacitors are to be tested, 12 specimens shall be taken for the tests on the X-capacitors and 12 other specimens for the tests on the Y-capacitors.

[c] Additional capacitors if lead-through capacitors are tested.

~~[d] See footnote h to Table 4.~~

[d] The smallest, a medium (in the case of more than four case sizes) and the largest case size shall be tested. Of each case size, three specimens of the maximum capacitance and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.

[e] Attention is drawn to the option of carrying out a combined voltage/current test, as ~~prescribed~~ described in 5.15.8.

Table 16 – Test schedule and sampling plan for lot-by-lot tests

Safety tests only			
Group	**Clause number and test referred to Clause 5 of this document**	**Inspection level IL**	**Acceptance number**
A0	5.3.2 Capacitance 5.3.4 Resistance[a] 5.3.1 Voltage proof [d]	100 %[b]	
A1	5.2 Visual examination Dimensions[c]	S-4	0
	5.3.5 Insulation resistance (Test A)	I	0
Tests in Group A0 and Group A2 can be made in any practical order, except for ceramic capacitors whose capacitance value shall be measured first. The sampling sizes corresponding to inspection levels should be selected from IEC 61193-2:2007, Table 1.			

[a] If applicable.

[b] May be carried out as end-of-line testing.

[c] This test may be replaced by in-production testing if the manufacturer installs SPC on dimensional measurements or other mechanisms to avoid parts exceeding limits.

[d] The voltage proof test shall be combined with a suitable monitoring method to detect defects in insulation resistance.

Table 17 – Test schedule for safety tests only

~~Subclause number and test~~ [a]	~~Conditions of test~~ [a]	~~n and c~~ [b]	~~Performance requirements~~ [a]
~~**Group 0**~~	~~**Non-destructive**~~	~~See Table 3~~	
~~4.1 Visual examination~~			~~No visible damage~~ ~~Legible marking~~
~~4.2.2 Capacitance~~			~~Within specified tolerance~~
~~4.2.4 Resistance (if applicable)~~			~~Within specified tolerance~~
~~4.2.1 Voltage proof~~	~~Method: …~~		~~No permanent break-down or flashover~~
~~4.2.5 Insulation resistance~~	~~Method: …~~		~~As in Table 11~~
~~**Group 1A**~~	~~**Destructive**~~	~~See Table 3~~	
~~4.1.1 Creepage distances and clearances~~			~~As 4.1.1~~
~~4.3 Robustness of terminations~~	~~Severity: see detail specification~~		~~No visible damage~~
~~4.4 Resistance to soldering heat (if applicable)~~	~~No pre-drying~~ ~~See detail specification for the Method 1~~		
~~4.20 Solvent resistance of the marking~~	~~Solvent: …~~ ~~Solvent temperature: …~~ ~~Method 1~~ ~~Rubbing material: cotton wool~~ ~~Recovery: …~~		~~Legible marking~~
~~4.4.2 Final measurements~~	~~Visual examination~~ ~~Capacitance~~ ~~Resistance (if applicable)~~		~~No visible damage~~ ~~See Table 13~~ ~~See Table 13~~
~~**Group 2**~~	~~**Destructive**~~	~~See Table 3~~	
~~4.12 Damp heat, steady state~~			
~~4.12.1 Initial measurements~~	~~Group 0 measurements to be used~~		
~~4.12.2 Test conditions~~	~~Ceramic capacitors: half of the sample with U_{R} applied; the other half with no voltage applied~~ ~~Other capacitors: no voltage applied~~		
~~4.12.3 Final inspection and measurements~~	~~Visual examination~~ ~~Capacitance~~ ~~Resistance (if applicable)~~ ~~Voltage proof~~ ~~Insulation resistance~~		~~No visible damage~~ ~~Legible marking~~ ~~See Table 15~~ ~~See Table 15~~ ~~See Table 15~~ ~~See Table 15~~

~~**Group 3**~~	~~**Destructive**~~	~~See Table 3~~	
~~4.13.1 Initial measurements~~	~~Group 0 measurements to be used~~		
~~4.13 Impulse voltage~~	~~3 pulses, full wave~~ ~~Peak voltage: see Table 1 and Table 2~~		~~See 4.13.2 and 4.13.3~~
~~4.14 Endurance~~	~~Duration: 1 000 h~~ ~~Voltage, current and temperature: see 4.14.3, 4.14.4, 4.14.5 and 4.14.6~~		
~~4.14.7 Final measurements~~	~~Visual examination~~		~~No visible damage~~ ~~Legible marking~~
	~~Capacitance~~		~~See Table 16~~
	~~Resistance (if applicable)~~		~~See Table 16~~
	~~Voltage proof~~		~~See Table 16~~
	~~Insulation resistance~~		~~See Table 16~~
~~**Group 6**~~	~~**Destructive**~~	~~See Table 3~~	
~~4.17 Passive flammability~~			~~See 4.17.1~~
~~**Group 7**~~	~~**Destructive**~~	~~See Table 3~~	
~~4.18 Active flammability~~			~~See 4.18.4~~

Subclause number and test [a]	**Conditions of test** [a]	***n* and *c*** [b]	**Performance requirements**[a]
Group 0	**Non-destructive**	See Table 15	
5.2 Visual examination	See 5.2.2		No visible damage Legible marking
5.3.2 Capacitance	See 5.3.2		Within specified tolerance
5.3.4 Resistance (if applicable)	See 5.3.4		Within specified tolerance
5.3.1 Voltage proof	See 5.3.1		No permanent break-down or flashover. No visible damage. The creepage distance and clearance specified in Table 3 shall be ensured. See detail specification
5.3.3 Tangent of loss angle (metallized film and paper capacitors only)	See 5.3.3		As in Table 5
5.3.5 Insulation resistance	See 5.3.5		

Subclause number and test [a]	**Conditions of test** [a]	n **and** c [b]	**Performance requirements**[a]
Group 1A	**Destructive**	See Table 15	
5.2.2 Creepage distances and clearances			As in 5.2.2
5.4 Robustness of terminations	See 5.4 Severity: see detail specification		No visible damage
5.5 Resistance to soldering heat (if applicable)	See 5.5.2 No pre-drying See detail specification for the Method		
5.21 Solvent resistance of the marking	Solvent: ... Solvent temperature: ... Method 1 Rubbing material: cotton wool Recovery: ...		Legible marking
5.5.3 Final inspection and measurements	Visual examination		No visible damage
	Capacitance		See Table 7
	Resistance (if applicable)		See Table 7
Group 2	**Destructive**	See Table 15	
5.13 Damp heat, steady state			
5.13.2 Initial measurements	Group 0 measurements to be used		
5.13.3 Test conditions	See 5.13.3		
5.13.4 Final inspection and measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 10 and Table 11
	Resistance (if applicable)		See Table 10 and Table 11
	Voltage proof		See Table 10 and Table 11
	Insulation resistance		See Table 10 and Table 11
	Tan δ (if applicable)		See Table 10 and Table 11

Subclause number and test [a]	**Conditions of test** [a]	n **and** c [b]	**Performance requirements**[a]
Group 3	**Destructive**	See Table 15	
5.14.2 Initial measurements	Group 0 measurements to be used		
5.14 Impulse voltage	See 5.14.3 Peak voltage, see Table 1 and Table 2		
5.14.4 Requirements	See 5.14.4		Minimum 3/24 full undisturbed pulses
5.15 Endurance	See 5.15.2 Duration: 1 000 h Voltage, current and temperature: see 5.15.4, 5.15.5, 5.15.6 and 5.15.7		No permanent breakdown or flashover
5.15.8 Final inspection and measurements	See 5.15.8 Visual examination		No visible damage Legible marking
	Capacitance		See Table 13
	Resistance (if applicable)		See Table 13
	Voltage proof		See Table 13
	Insulation resistance		See Table 13
	Tan δ (if applicable)		See Table 13
Group 6	**Destructive**	See Table 15	
5.18 Passive flammability	See 5.18.1.1		See 5.18.1.2
Group 7	**Destructive**	See Table 15	
5.19 Active flammability	See 5.19.2		See 5.19.3

Tests in Group 0 can be carried out in any practical order, except for ceramic capacitors the capacitance value shall be measured first.

[a] Subclause numbers of test conditions and requirements refer to Clause 5.

[b] n = number of specimens, c = number of permissible nonconforming items.

[c] When, for a ceramic capacitor, a precise measurement of capacitance drift is required, preconditioning according to Annex G should be performed as advised by the manufacturer.

8.5 Quality conformance inspection

8.5.1 General

Before submission to the quality conformance inspection, an appropriate 100 % voltage proof test between terminations in accordance with Table 4 shall be carried out.

The details of this test shall be the prerogative of the manufacturer, but the time shall be not less than 1 s.

If the test is performed in a time period between 1 s and 2 s, the voltage of Table 4 shall be increased to values above curve B of Figure 9.

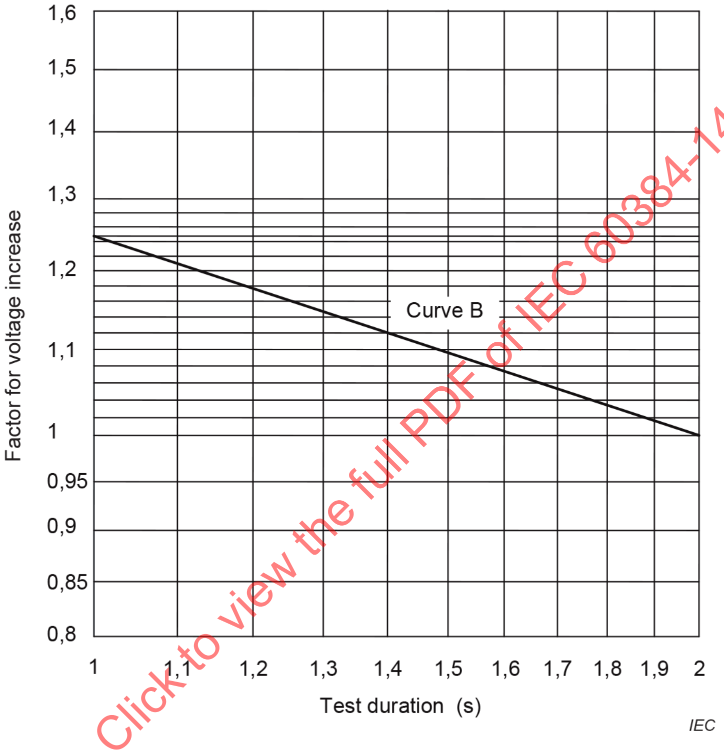


Figure 9 – ~~Test duration (s)~~ Increased voltage for tests below 2 seconds

If a DC test voltage is used instead of AC for Y-capacitors, it shall be not less than 1,5 times the AC test voltage in Table 4 and further increased to values above curve B of Figure 9.

All nonconforming items shall be removed from the lot prior to lot-by-lot testing.

8.5.2 Formation of inspection lots

8.5.2.1 Group A ~~and B~~ inspection

These tests shall be carried out on a lot-by-lot basis in accordance with Table 15.

A manufacturer may aggregate the current production into inspection lots, subject to the following safeguards:

a) the inspection lot shall consist of structurally similar capacitors (see 8.2);

b) the sample tested shall be representative of the values and dimensions contained in the inspection lot:

   1) in relation to their number;

   2) with a minimum of five of any one value;

c) if there are less than five of any one value in the sample the basis for the drawing of samples shall be agreed between the manufacturer and the Certification Body.

For Group A tests, the inspection lot shall consist of components of the same rated voltage, class and subclass and shall be taken from one continuous production run.

No nonconforming items are permitted for Class Y-capacitors in the voltage proof test.

~~For Group B tests, the inspection lot shall consist of components produced with similar processes and materials, as related to the test concerned.~~

8.5.2.2 Group C inspection – Safety tests only approval

Re-qualification tests in accordance with Table 17 may be required by the certification body when a change of the declared design as given in Annex D is intended.

The certification body shall be informed about the intended change(s) and decide whether re-qualification tests ~~have to~~ shall be performed.

~~3.5.1.2.2 Qualification approval~~

~~These tests shall be carried out on a periodic basis.~~

~~The samples to be submitted to the periodic test in Table 8 shall be representative of the current production of the specified periods and shall be taken from the same rated voltage, class and subclass. In subsequent periods, other case sizes in production shall be tested with the aim of covering the whole range of the approval.~~

~~No nonconforming items are permitted for Class Y capacitors in the voltage proof test.~~

~~3.5.2 Test schedule~~

8.5.3 Test schedule for safety tests only approval

The schedule for the lot-by-lot tests or criteria for re-qualification is given in Table 16 and Annex D.

~~3.5.2.2 Test schedule for qualification approval~~

~~The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in Table 4 of Clause 2 of the blank detail specification, for example, IEC 60384-14-3.~~

8.5.4 Delayed delivery

Re-inspection in the case of delayed delivery shall be carried out at intervals not exceeding three years. When according to the procedures of IEC 60384-1:~~2008~~2021, Q.1.7, re-inspection ~~has to~~ shall be made, voltage proof at the full relevant test voltage, capacitance, resistance (if applicable) and insulation resistance shall be checked as specified in Group A inspection and solderability shall be checked according to Group B inspection.

8.5.5 Assessment level

The assessment level DZ will be used. See Table 18.

Table 18 – Assessment level

	DZ		
Inspection subgroup [b]	**IL**	**Acceptance number**	
A1	S-4	0	
A2	I	0	
B1	S-3	0	
Inspection subgroup [b]	**DZ**		
	p	n	c [a]
C1A	6	6	0
C1B ~~[c]~~	6	12	0
C1	6	18	0
C2	6	~~10~~ 12	0
C3	3		0
Class X		12	
Class Y		12	
Lead through		6	
C4	6	6	0
C5	12	4	0
C6	12	6 to 18	0
C7	12	24	0

The sampling sizes corresponding to inspection levels should be selected from IEC 61193-2:2007, Table 1.

IL = inspection level

p = periodicity in months

n = sample size

c = permissible number of nonconforming items

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] The content of the inspection subgroups is described in the relevant blank detail specification.

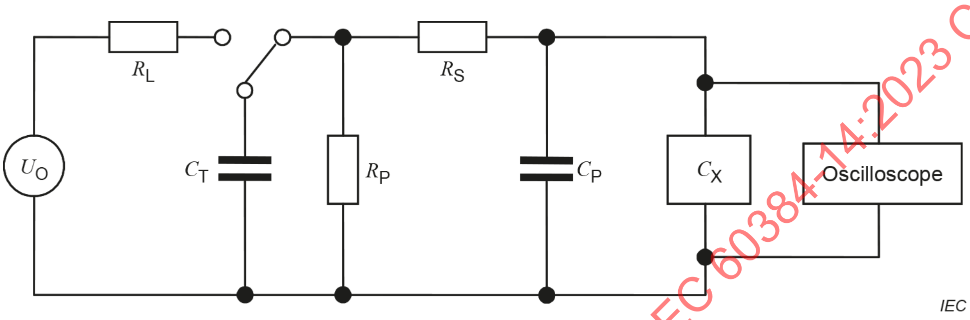
[c] The vibration, bump and shock tests in this subgroup are required to be carried out every 12 months only.

Annex A
(normative)

Circuit for the impulse voltage test

~~It has to be pointed out that~~ The 1,2/50 pulse shape in equipment standards, for example in ~~IEC 60065:2001, Annex K and in IEC 60950-1:2005, Annex N~~ IEC 62368-1:2018, Annex D, is defined under open circuit conditions, and a different shape is accepted in under load conditions.

The test prescribed in 5.14 shall be carried out using the circuit of Figure A.1 and the values given in Table A.1, as well as the values and tolerances given in Table A.2.



C_T = charging (or tank) capacitor

C_P = parallel capacitor

C_X = capacitor under test

R_L = loading resistor

R_S = series resistor, or charging resistor

R_P = parallel resistor, or discharging resistor

U_O = direct voltage source

Figure A.1 – Impulse voltage test circuit

Table A.1 – Values of C_X, C_T, R_P, R_S, C_p

~~Nominal value of C_X~~ ~~µF~~	~~C_T~~ ~~±10 %~~ ~~µF~~	~~R_P~~ ~~±10 %~~ ~~Ω~~	~~R_S~~ ~~±10 %~~ ~~Ω~~	~~C_p~~ ~~±10 %~~ ~~pF~~
~~$C_X \leq 0{,}003\,9$~~	~~0,25~~	~~234~~	~~62~~	~~7 800~~
~~$0{,}003\,9 < C_X \leq 0{,}012$~~	~~0,25~~	~~234~~	~~45~~	~~7 800~~
~~$0{,}012 < C_X \leq 0{,}018$~~	~~0,25~~	~~234~~	~~27~~	~~7 800~~
~~$0{,}018 < C_X \leq 0{,}027$~~	~~0,25~~	~~234~~	~~27~~	~~–~~
~~$0{,}027 < C_X \leq 0{,}039$~~	~~20~~	~~3~~	~~25~~	~~3 300~~
~~$0{,}039 < C_X \leq 0{,}056$~~	~~20~~	~~3~~	~~13~~	~~3 300~~
~~$0{,}056 < C_X \leq 0{,}082$~~	~~20~~	~~3~~	~~9~~	~~3 300~~
~~$0{,}082 < C_X \leq 0{,}12$~~	~~20~~	~~3~~	~~7~~	~~3 300~~
~~$0{,}12 < C_X \leq 0{,}18$~~	~~20~~	~~3~~	~~5~~	~~3 300~~
~~$C_X > 0{,}18$~~	~~20~~	~~3~~	~~3~~	~~3 300~~

Nominal value of C_X nF	C_T ±10 % µF	R_P ±10 % Ω	R_S ±10 % Ω	C_p ±10 % nF
$C_X \leq 3{,}9$	0,25	234	62	7,8
$3{,}9 < C_X \leq 12$	0,25	234	45	7,8
$12 < C_X \leq 18$	0,25	234	27	7,8
$18 < C_X \leq 27$	0,25	234	27	–
$27 < C_X \leq 39$	20	3	25	3,3
$39 < C_X \leq 56$	20	3	13	3,3
$56 < C_X \leq 82$	20	3	9	3,3
$82 < C_X \leq 120$	20	3	7	3,3
$120 < C_X \leq 180$	20	3	5	3,3
$C_X > 180$	20	3	3	3,3

Table A.2 describes the reference values and tolerances of C_X, t_r, and t_d to verify the test circuit setup.

Table A.2 – Values and tolerances of C_X, t_r, t_d

C_X ±2 %	t_r (0/+50) %	t_d (0/+50) %
µF	µs	µs
0,01	1,7	46
0,1	1,6	47

Annex B
(normative)

Circuit for the endurance test

The test prescribed in 5.15 shall be carried out with the following circuit (see Figure B.1).

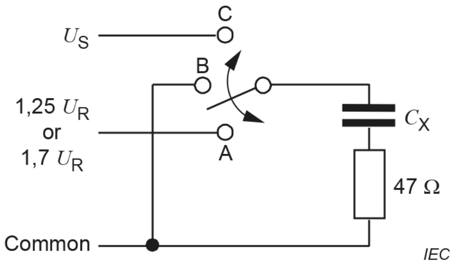


Figure B.1 – Endurance test circuit

C_X = capacitor under test.

U_S = 1,5 × U_R or 1 000 V RMS, whichever is higher

The part of the circuit for discharging the capacitor may be omitted if the switching between the two supplies is arranged to take place at the zero voltage point on the sinusoidal wave.

When the discharging circuit is used, the switching shall be arranged in the following sequence for each occasion when U_S is applied:

a) switch from position A to position B. Time for switching and remaining on position B is t_1;

b) switch from position B to position C. Time for switching and remaining on position C is t_2. Time on position C is 0,1 s;

c) switch from position C to position B. Time for switching and remaining on position B is t_3;

d) switch from position B to position A. Time for switching is t_4.

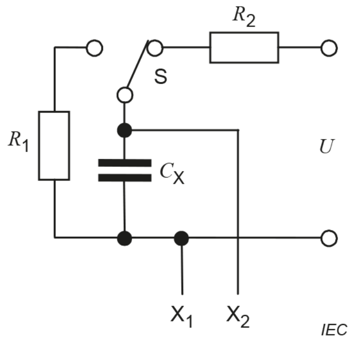
For any capacitor under test, the following condition shall be fulfilled:

$$t_1 + t_2 + t_3 + t_4 \leq 30 \text{ s}$$

Annex C
(normative)

Circuit for the charge and discharge test

The test prescribed in 5.16 shall be carried out with the following circuit (see Figure C.1).



C_X = capacitor under test

R_1 = current-limiting resistor (discharge)

R_2 = current-limiting resistor (charge)

S = switching device

U = test voltage

X_1, X_2 = terminals for oscilloscope connection to observe the maximum rate of change of voltage

Figure C.1 – Charge and discharge test circuit

Annex D
(normative)

Declaration of design
(confidential to the manufacturer and the certification body)

The purpose of this description is to register essential data and the basic design of the capacitors for which approval is sought. The completed form shall be submitted to the relevant certification body prior to any approval testing; its circulation to the other parties is left to the decision of the manufacturer.

Changes to the declared design are permitted only after notifying the certification body in writing. In this case, the certifying body will decide on necessary steps to be taken. As a maximum, a complete re-qualification ~~may~~ can be required.

Registration number:

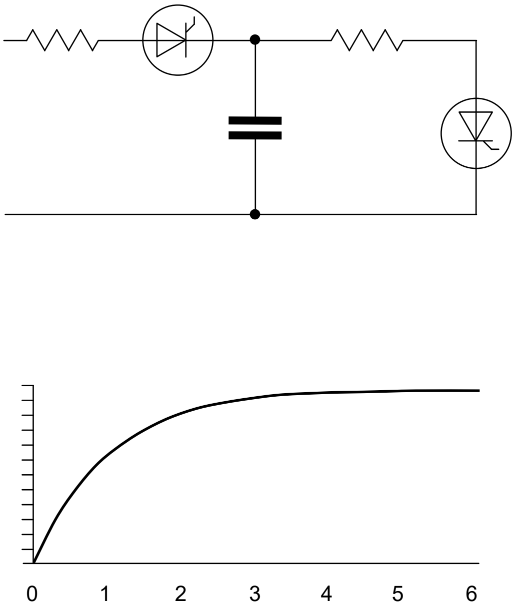
(To be allocated by the certifying body)

1 **Applicant**
2 **Manufacturer**
3 **Manufacturing site**
4 **Type designation**
5 **Class/subclass**
6 **Circuit diagram**
7 **Dielectric:**
7.1 Material
7.2 Thickness
7.3 Density (paper only)
7.4 Number of individual layers
8 **Electrode(s):**
8.1 Material
8.2 Method of production of electrode:
(For example, foil, evaporated onto film or paper)
9 **Capacitor element, arrangement of the individual layers**
10 **Impregnant** (if applicable)
11 **Encapsulation:**
11.1 Material(s) for cases, resins, etc. (as applicable)
11.2 Material of outer insulation (if applicable)
12 **Outline dimensions**

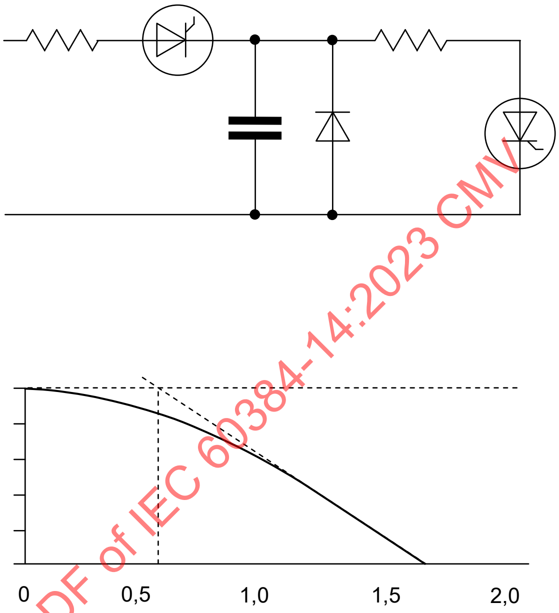
Location	Date	Name	Signature

Annex E 18
(informative)

Pulse test circuits



IEC 1328/13



IEC 1329/13

~~**Charge waveform for both circuits:**~~

~~Timescale in units of RC (R is the charge resistor)~~

~~The maximum value of d*U*/d*t* is derived as follows:~~

~~*Q* = *CU* where *Q* is the charge on the capacitor and hence~~

$$I = C\frac{\mathrm{d}U}{\mathrm{d}t}$$

$$\left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{I_{\max}}{C}$$

~~**Discharge waveform for inductive circuit:**~~

~~Time scale in units of~~ √LC

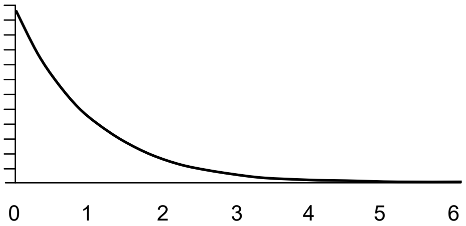
~~For the inductive circuit, if dissipation is neglected, the inductive energy with the initial capacitive energy:~~

$$\frac{1}{2}LI_{\max}^2 = \frac{1}{2}CU_0^2$$

$$I_{\max} = U_0\sqrt{\frac{C}{L}}$$

$$\left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{U_0}{\sqrt{LC}}$$

~~which occurs at~~ $t = \pi / 2\sqrt{LC}$



IEC 1330/13

~~**Discharge waveform for resistive circuit:**~~

~~Time scale in units of RC (R is the discharge resistor)~~

~~For the resistive circuit~~

$$I_{\max} = \frac{U_0}{R}$$

$$\left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{U_0}{RC}$$

~~which occurs at $t = 0$.~~

~~Also since~~

$$U = L\frac{\mathrm{d}L}{\mathrm{d}t}$$

$$\left.\frac{\mathrm{d}L}{\mathrm{d}t}\right|_{\max} = \frac{U_0}{L}$$

~~This gives control of~~ $\left.\frac{\mathrm{d}L}{\mathrm{d}t}\right|_{\max}$

~~and thus enables to avoid exceeding this rating of the switch in the discharge circuit. In the resistive circuit, there is no such control and the rating is liable to be exceeded when trying to achieve peak discharge of a hundred or more amperes.~~

E.1 General

This annex describes alternative pulse testing circuits.

E.2 Test circuits

Figure E.1 shows the resistive pulse test circuit alternative and Figure E.2 the inductive test circuit alternative.

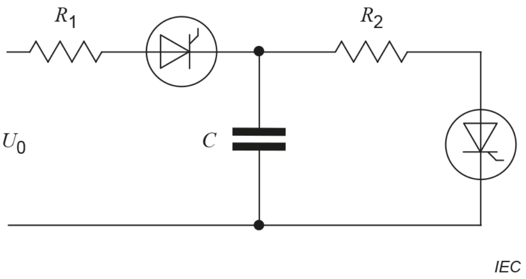


Figure E.1 – Resistive pulse test circuit

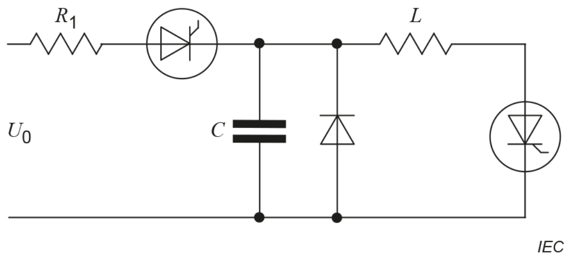


Figure E.2 – Inductive pulse test circuit

E.3 Charging of the capacitor

Figure E.3 shows the charging waveform for both test circuits, which is the same in both cases.

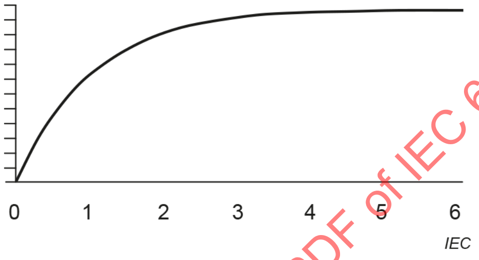


Figure E.3 – Charge waveform for both circuits

Timescale is in units of R_1C (R_1 is the charge resistor). The maximum value of dU/dt is derived as follows:

$Q = CU$, where Q is the charge on the capacitor and hence

$$I = C\frac{\mathrm{d}U}{\mathrm{d}t} \rightarrow \left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{I_{\max}}{C}$$

E.4 Discharging of the capacitor

E.4.1 Discharging in resistive circuit

Figure E.4 shows the discharge waveform for the resistive circuit.

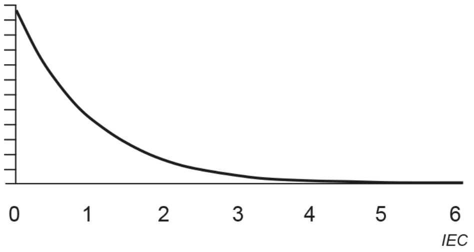


Figure E.4 – Discharge waveform for resistive circuit

Time scale is in units of R_2C (R_2 is the discharge resistor)

For the resistive circuit $I_{\text{max}} = \frac{U_0}{R}$ ->

$$\left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\text{max}} = \frac{U_0}{RC}$$

which occurs at t = 0.

E.4.2 Discharging in inductive circuit

Figure E.5 shows the discharge waveform for the inductive circuit.

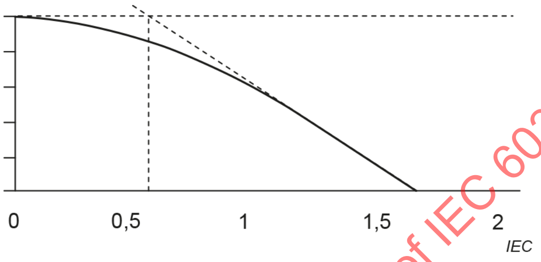


Figure E.5 – Discharge waveform for inductive circuit

Time scale is in units of $\sqrt{LC}$.

For the inductive circuit, if dissipation is neglected, the inductive energy with the initial capacitive energy is:

$$\frac{1}{2}LI_{\text{max}}^2 = \frac{1}{2}CU_0^2 \text{ -> } I_{\text{max}} = U_0\sqrt{\frac{C}{L}} \text{ -> } \left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\text{max}} = \frac{U_0}{\sqrt{LC}}$$

which occurs at $t = \pi / 2\sqrt{LC}$.

Also since $U = L\frac{\mathrm{d}L}{\mathrm{d}t}$ > $\left.\frac{\mathrm{d}L}{\mathrm{d}t}\right|_{\text{max}} = \frac{U_0}{L}$, this gives control of $\left.\frac{\mathrm{d}L}{\mathrm{d}t}\right|_{\text{max}}$ and thus enables to avoid exceeding this rating of the switch in the discharge circuit.

In the resistive circuit, there is no such control, and the rating is liable to be exceeded when trying to achieve peak discharge.

Annex F
(normative)

Particular requirements for safety test of surface mount~~ing~~ capacitors

F.1 General

Surface mount~~ing~~ capacitors shall, in general, comply with all safety requirements of this document. Design, material, and mounting technology make it necessary to introduce new tests and adjust some existing methods and requirements.

The following paragraphs replace corresponding paragraphs in the main section of this document.

6.3 Marking of capacitors

The capacitors shall be clearly marked with a) and b) in Clause 6. The capacitors may also be marked with as many of the remaining items as possible taking account of the relative importance of each item. The marking shall be sufficient to enable a clear identification of the component.

7.3 Mounting

According to IEC 60384-1:~~2008~~2021, 5.5 for the safety test according to Table F.1, the manufacturer shall supply the test house with components unmounted or mounted on individual substrates, as indicated in Table F.1. The suitability of a proposed substrate shall be agreed between the manufacturer and the test laboratory. Details of the substrate, or substrates, used for the testing shall be included in the test report. An example of a substrate with conductive tracks is shown in Figure F.1.

~~1.5.21 Surface mount capacitor~~

~~A capacitor whose small dimensions and nature of shape of terminations make it suitable for surface mounting in hybrid circuits and on printed boards.~~

F.2 Test and measurement procedures

The capacitor shall be tested in accordance with Table F.1 with the following deviations.

For an unencapsulated capacitor, test C in 5.3.1 and 5.3.5 shall be omitted.

5.3 Robustness of terminations is substituted with IEC 60384-1:~~2008~~2021, 7.7 and IEC 60384-1:2021, 7.8 and performed before the tests in Groups 2 and 3. Measurement of capacitance during the bending test may be omitted.

5.4 Resistance to soldering heat, if applicable, is performed as a separate test in accordance with IEC 60384-1:~~2008~~2021, 9.1.2.

5.5.3 Final inspection, measurements, and requirements

The capacitors shall be visually examined and measured and shall meet the requirements of Table 7.

Table F.1 – Test schedule and sampling plan for safety test of surface mount capacitors

Group	Clause number and test referring to Clause 5		Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass	
				Per group	Total
0	5.2	Visual examination [a]			
	5.3.2	Capacitance	~~28~~ 30 + 12[d] +		
	5.3.4	Resistance [c]	6 [f] + (6 to 18) [f] +	0	
	5.3.1	Voltage proof	24		
	5.3.5	Insulation resistance			
	5.3.3	Tangent of loss angle (metallized film and paper capacitors only)			
		Spares	14 + 6 [e]		
1A	5.2.2	Creepage distances and clearances [a]			
	5.5	Resistance to soldering heat [a, c]	6	0 [b]	
	5.21	Solvent resistance of the marking [a]			
	5.18	Passive flammability [a]	6 to 18 [f]	0	
	Mounting according to 7.3		10 + 12 [d] + 6 [e] + 24		
2	7.7	of IEC 60384-1:~~2008~~2021, Shear test [g]	~~10~~ 12	0 [b]	
	7.8	of IEC 60384-1:~~2008~~2021, Substrate bending test			
	5.13	Damp heat, steady state			
3	7.7	of IEC 60384-1:~~2008~~2021, shear test [g]			0
	7.8	of IEC 60384-1:~~2008~~2021, substrate bending test			
	5.14	Impulse voltage			
	5.15	Endurance		0 [b]	
	5.15.5	Class X and RC units	12 [d]		
	5.15.6	Class Y and RC units	12 [d]		
	5.15.7	Lead-through	6 [e]		
4	5.19	Active flammability	24	0	

- Tests in Group 0 can be made in any practical order, except for ceramic capacitors whose capacitance value shall be measured first.
- Attention is drawn to the option of carrying out a combined voltage/current test as prescribed in 5.15.7.

[a] Samples for 5.2, 5.2.2, 5.5, 5.21 and 5.18 shall not be mounted on substrate during test.

[b] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted. The nonconforming items obtained in the first sample shall be counted for the total of nonconforming items permitted in the last column.

[c] If applicable.

[d] If multi-section capacitors consisting of X- and Y-capacitors are to be tested, 12 specimens shall be taken for the tests on the X-capacitors and 12 other specimens for the tests on the Y-capacitors.

[e] Additional capacitors if lead-through capacitors are tested.

[f] The smallest, a medium (in the case of more than four case sizes), and the largest case size shall be tested. Of each case size, 3 specimens of the maximum capacitance and 3 specimens of the minimum capacitance shall be tested, resulting in 6 specimens per case size.

[g] This test is to be performed alternatively to the substrate bending test, if the detail specification specifies mounting on rigid substrate (for example, alumina) only.

Dimensions in millimetres

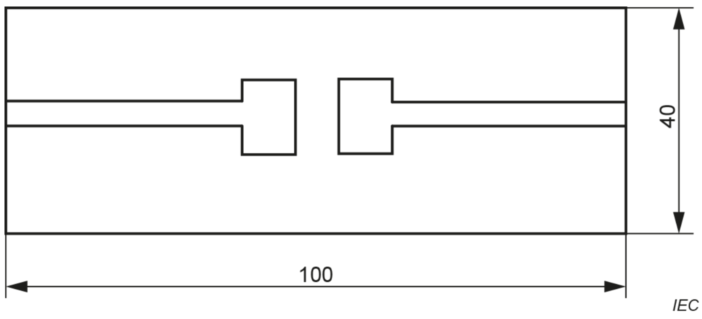


Figure F.1 – Example of test substrate for safety test according to Table F.1

Annex G
(informative)

Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

G.1 Overview

Most ~~ceramic~~ Class 2 dielectrics used for ceramic capacitors have ferroelectric properties and exhibit a Curie temperature.

Above this temperature, the dielectric has the highly symmetric cubic crystal structure whereas below the Curie temperature the crystal structure is less symmetrical. Although in single crystals this phase transition is very sharp, in practical ceramics it is often spread over a finite temperature range, but, in all cases, it is linked with a peak in the capacitance/temperature curve.

Under the influence of thermal vibration, the ions in the crystal lattice continue to move to positions of lower potential energy for a long time after the dielectric has cooled through the Curie temperature. This gives rise to the phenomenon of capacitance ageing, whereby the capacitor continuously decreases its capacitance.

However, if the capacitor is heated to a temperature above the Curie temperature, then de-ageing takes place, i.e. the capacitance lost through ageing is regained, and ageing recommences from the time when the capacitor re-cools.

G.2 Law of capacitance ageing

During the first hour after cooling through the Curie temperature, the loss of capacitance is not well defined, but after this time it follows a logarithmic law (see K.W. Plessner, Proc. Phys. Soc., vol. 69B, P1261, 1956) which can be expressed in terms of an ageing constant.

The ageing constant k is defined as the percentage loss of capacitance due to the ageing process of the dielectric which occurs during a "decade", i.e., a time in which the capacitor increases its age tenfold, for example, from 1 h to 10 h.

As the law of decrease of capacitance is logarithmic, the percentage loss of capacitance will be 2 × k between 1 h and 100 h age and 3 × k between 1 h and 1 000 h age. This may be expressed mathematically by the following equation:

$$C_t = C_1\left(1 - \frac{k}{100} \times \lg t\right)$$

where

C_t is the capacitance t h after the start of the ageing process;

C_1 is the capacitance 1 h after the start of the ageing process;

k is the ageing constant in percent per decade (as defined above);

t is the time in h from the start of the ageing process.

The ageing constant may be declared by the manufacturer for a particular ceramic dielectric, or it may be defined by de-ageing the capacitor and measuring the capacitance at two known times thereafter.

k is then given by the following equation:

$$k = \frac{100 \times (C_{t_1} - C_{t_2})}{C_{t_1} \times \lg t_2 - C_{t_2} \times \lg t_1}$$

If capacitance measurements are made three or more times, then it is possible to derive k from the slope of a graph where C_t is plotted against lg t.

It is also possible to plot lg C against lg t.

During measurements of ageing the capacitor should be maintained at a constant temperature so that capacitance variations due to the temperature characteristic do not mask those due to ageing.

G.3 Capacitance measurements and capacitance tolerance

Because of ageing, it is necessary to specify a reference age at which the capacitance shall be within the prescribed tolerance. This age is fixed at 1 000 h, since, for practical purposes, there is not much further loss of capacitance after this time.

In order to calculate the capacitance $C_{1\,000}$ after 1 000 h, the ageing constant shall be known or determined as in Clause G.2, when the following formula may be used:

$$C_{1\,000} = C_t \left[1 - \frac{k}{100} (3 - \lg t) \right]$$

$$C_t = C_1 \left(1 - \frac{k}{100} \times \lg t \right)$$

For factory measurements, the loss of capacitance from the age at time of measurement to 1 000 h age will be known and can be offset by using asymmetric inspection tolerances.

For example, if it is known that the capacitance loss will be 5 %, then the capacitors may be inspected to limits of +25/−15 % instead of ±20 %.

Capacitance is normally declared at 20 °C, and it may be necessary to measure at this temperature or correct the results to this temperature. Errors can also arise from the hand temperature, and capacitors should therefore always be handled with plastic tweezers.

G.4 Special preconditioning

In many of the tests in this document, it is required to measure the capacitance change which results from a given conditioning (for example, climatic sequence). In order to avoid the interfering effect of ageing, the capacitor is specially preconditioned before these tests by maintaining it for 1 h at the upper category temperature followed by 24 h at standard atmospheric conditions for testing.

For those capacitors with a Curie temperature below the upper category temperature, this results in de-ageing and the conditioning is also arranged, if possible, to bring the capacitors to an age of 24 h, so that capacitance changes due to ageing are minimized.

If the Curie temperature of the dielectric is above the upper category temperature, then the special preconditioning will not completely de-age the capacitor, but it will nevertheless bring it into a state where its capacitance is not so dependent on its previous history. In order to de-age such capacitors completely, a temperature up to 160 °C may be required, and this temperature could be deleterious to the encapsulation. Therefore, in the few cases where complete de-ageing of such capacitors may be required, the detail specification shall be consulted for details and any necessary precautions.

Annex H
(normative)

Use of safety approved AC rated capacitors in DC applications

H.1 Overview

This annex gives additional requirements for AC EMI suppression capacitors for which safety approval is sought and which are connected to a DC supply with nominal voltage not exceeding 1 500 V DC.

If a safety approved capacitor fulfils the requirements of this annex, it is qualified at the rated DC voltage exceeding its approved rated AC voltage (RMS), without changing the capacitor class.

The manufacturer of the capacitor shall define the intended rated DC voltage, U_R DC, if it will exceed the certified rated AC voltage U_R AC. 19

H.2 Background

Safety capacitors approved to this document are AC capacitors which are essentially designed for applications where AC voltage is applied.

They have been allowed to be used in DC supplies having the same voltage as the rated AC voltage (RMS) of the capacitors. (See 3.1.1, Note 1 to entry).

The class of the capacitors, such as X1 and Y1, is defined according to their peak impulse withstanding voltage and the type of insulation bridged.

A capacitor used for AC voltage application is subjected to the voltage waveform with peak voltage equal to RMS voltage times square root of two, which is alternating polarity in a wave cycle, so that safety approved capacitors theoretically can withstand at least a DC voltage equivalent to their rated AC voltage times square root of two.

NOTE Many manufacturers are specifying that their AC capacitors can withstand clearly higher DC voltages than rated AC voltage times the square root of two.

~~H.3 Terms and definitions~~

~~H.3.1~~
~~**d.c. rated voltage**~~
~~U_R d.c.~~

~~maximum d.c. operating voltage, which may be applied continuously to the terminations of a capacitor at any temperature between the lower and the upper category temperatures~~

~~Note 1 to entry: This term and designation (U_R d.c.) are used only for a capacitor specified with d.c. rated voltage exceeding its a.c. r.m.s. rated voltage.~~

~~Note 2 to entry: This definition replaces that given in IEC 60384-14:2013, 1.5.1.~~

H.3 Additional requirement for use of X- and Y-capacitors in DC applications

A capacitor, which is specified for rated DC voltage exceeding the rated AC voltage (RMS), shall fulfil the requirements specified in Table H.1 in addition to the tests ~~prescribed~~ listed in Table 13.

Table H.1 – Additional test conditions

Type	Maximum U_R DC	Test voltage DC (Test A) (according 5.3.1)	Endurance test (DC)	Damp heat, steady state test
X1	1 500 V	2,15 × U_R DC	In accordance with 5.15 using rated DC voltage instead of U_R, without voltage increased to U_S.	In accordance with 5.13, but with rated DC voltage applied to ~~the whole~~ a sample of 6 pcs. See Table 12.
X2	1 500 V			
Y1	1 500 V	4 × U_R DC [a]		
Y2	1 500 V	2,15 × U_R DC [a]		
Y4	450 V	2,15 × U_R DC [a]		

[a] If an AC test voltage is used instead of a DC voltage for Y-capacitors, it shall be not less than 0,666 × DC test voltage in Table H.1.

NOTE As an example, a typical X2 capacitor on the market, has rated AC voltage 300 V and rated DC voltage, U_R DC, 630 V. This means that the test voltage DC (Test A) is 2,15 × 630 V = 1 354,5 V.

H.4 Creepage and clearance distances

When a capacitor approved by this annex is used for a specific application, it shall be confirmed that creepage and clearance distances of the capacitor meet the requirements of the related standards for the application.

NOTE For examples of the specific standards and the requirements mentioned above, see IEC 60939-3:2015, Table 6 and Table 7.

Annex I
(normative)

Humidity robustness grades for applications, where high stability under high humidity operating conditions is required

I.1 Overview

In addition to the description of preferred climatic categories in 4.1 and test damp heat, steady state in 5.13, this annex describes specific humidity robustness grades and requirements for applications, where high stability under high humidity operating conditions is required.

I.2 Humidity robustness grades

I.2.1 General

For high humidity applications the Grade (I) robustness under humidity, Grade (II) robustness under high humidity and Grade (III) high robustness under high humidity are defined.

I.2.2 Grade (I) robustness under humidity

To verify Grade (I), either test condition A or B shall be selected by the manufacturer. ~~For requirements, see Table I.1. In case the capacitors are specified for a.c. and d.c. applications, one sample shall be tested with the rated a.c. voltage, and one sample shall be tested with rated d.c. voltage.~~

Test condition A: Test damp heat, steady state; 40 °C ± 2 °C / (93 ± 3) % RH duration 21 days, rated voltage applied.

Test condition B: Test damp heat, steady state; 85 °C / 85 % RH duration 7 days (= 168 h), rated voltage applied.

NOTE Test condition B is a substitutional ~~acceleration~~ accelerated test for test condition A.

I.2.3 Grade (II) robustness under high humidity

To verify Grade (II), either test condition A or B shall be selected by the manufacturer. ~~For requirements see Table I.1. In case the capacitors are specified for a.c. and d.c. applications, one sample shall be tested with the rated a.c. voltage, and one sample shall be tested with rated d.c. voltage.~~

Test condition A: Test damp heat, steady state; 40 °C ± 2 °C / (93 ± 3) % RH duration 56 days, rated voltage applied.

Test condition B: Test damp heat, steady state; 85 °C / 85 % RH duration 500 h, rated voltage applied.

NOTE Test condition B is a substitutional ~~acceleration~~ accelerated test for test condition A.

I.2.4 Grade (III) high robustness under high humidity

To verify Grade (III), either test condition A or B shall be selected by the manufacturer. ~~For requirements, see Table I.1. In case the capacitors are specified for a.c. and d.c. applications, one sample shall be tested with the rated a.c. voltage, and one sample shall be tested with rated d.c. voltage.~~

Test condition A: Test damp heat, steady state; 60 °C ± 2 °C / (93 ± 3) % RH duration 56 days, rated voltage applied.

Test condition B: Test damp heat, steady state; 85 °C / 85 % RH duration 1 000 h, rated voltage applied.

NOTE Test condition B is a substitutional ~~acceleration~~ accelerated test for test condition A.

I.3 Test description 20

If the capacitors are specified for AC applications, one sample of ten pieces shall be tested with the rated AC voltage. If the capacitors are specified also for DC applications, and the rated DC voltage is exceeding the rated AC voltage (RMS), one additional sample of six pieces shall be tested with rated DC voltage. See Table 12. For requirements, see Table I.1.

Table I.1 – Requirements

Measurement	Measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	Metalized capacitors: $\lvert \Delta C \rvert$ ≤10 % Ceramic capacitors: $\lvert \Delta C \rvert$ ≤15 %
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,024 for C_N ≤ 1 µF [a] 0,015 for C_N > 1 µF [a]
Resistance (if applicable)	5.3.4	$\lvert \Delta R/R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage as in Table 4
Insulation resistance	5.3.5	> 50 % of the applicable limits of Table 5 or Table 6, or minimum 200 MΩ, whichever is higher

The change of capacitance value depends on technology, and, as for example in case of ceramic capacitors, can be reversible. Thus, the requirements are different.

[a] For certain applications, smaller values for the increase of tan δ may be required.

I.4 Indication of humidity robustness grades

In addition to the climatic category, information on the humidity robustness grade and the test method used for verification shall be indicated IA, IB, IIA, IIB, IIIA, or IIIB in the information provided by the manufacturer. Marking on the capacitor is not required.

Annex J 21

(normative)

Description of creepage/clearance distance measurement for cased and conformal coated capacitors

J.1 Measurement of creepage distances and clearance – general

J.1.1 General

Capacitors complying with this document are permitted to bridge certain levels of insulation. They are produced in various styles and shapes, using different encapsulation methods. All this can affect how the creepage distance and clearance is defined and measured. This annex gives an overview of different capacitor styles and how the creepage and clearance distances are determined in each case. In addition, it provides information about precautions in handling, in order not to cause damage to external insulation and coating of terminal pins.

For other capacitor styles than cased or conformal coated, the manufacturer shall define the clearance and creepage distances.

J.1.2 Capacitor styles

Figure J.1 and Figure J.2 show examples of cased and conformal coated capacitors.

Figure J.1 – Example of a cased capacitor

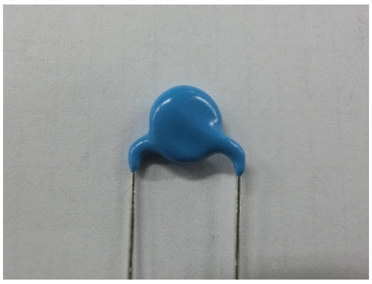


Figure J.2 – Example of a conformal coated capacitor

J.1.3 Capacitor body and terminal insulation

The case, or the coating comprising the case, shall fulfil the requirements of this document, which is ensured by design and by tests of the capacitor body's insulation. In the case of conformal coated capacitors, the design shall provide the minimum thickness of coating material. See Figure J.3, white part.

EXAMPLE A subclass Y1 capacitor is permitted to bridge double or reinforced insulation. The capacitor case or coating serves as double or reinforced insulation to other circuit parts, such as a transformer core or other conductive parts.

The coating on terminals (Figure J.3, grey area) is insulating the metallic leads and is defined as functional insulation (solid insulation material). Because its thickness and breakdown strength are not specified, it cannot be considered as a basic insulation.

It is important to note the different classification of a functional insulation depending upon the context it is used. It can be "conductive" as well as "insulation":

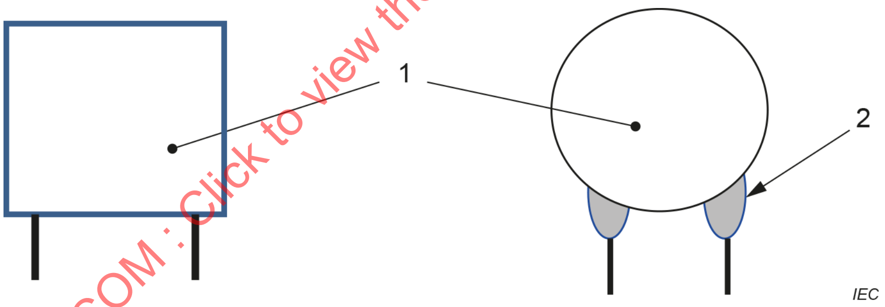
- For creepage distance, the relevant property is that it is a solid insulating material (non-conductive), independent from its thickness and breakdown strength.

  NOTE 1 Creepage distance is the shortest distance along the surface of a solid insulating material between two conductive parts(see IEC 60050-151, 151-15-50 and IEC 60050-581, 581-21-23).

- For clearance, the relevant property is the breakdown strength. The breakdown strength of a functional insulation is not specified, and when not tested, it shall be classified as conductive. In consequence, that means:
  - i) for clearance between the terminals, the breakdown strength of the insulation is tested by the voltage proof test (5.3.1, Test A), thus it fulfils the same requirements as the capacitor body's insulation;
  - ii) for clearance from a terminal to outside the capacitor, the breakdown strength of the insulation is not tested, thus the coating of the leads shall be classified as conductive to determine the clearance.

  NOTE 2 Clearance is the shortest distance in air between two conductive parts (see IEC 60050-581, 581-27-76).

Further details are given in Clause J.2.



Key:

1 Capacitor body insulation (case or conformal coating) – insulation is specified and tested

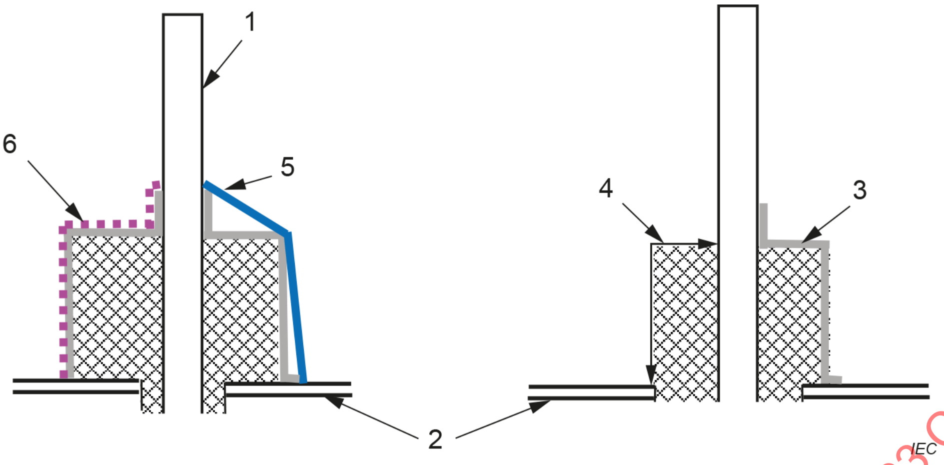
2 Coating on terminal – insulation is not specified, but tested between the terminals

Figure J.3 – Cased and conformal coated types

J.1.4 Measurement principle

Coatings may be used over external terminations of components to increase effective clearances and creepage distances (see Figure J.4). The mechanical arrangement and rigidity of the terminations shall be adequate to ensure that, during normal handling, assembly into equipment and subsequent use, the terminations will not be subject to deformation that would crack the coating or reduce the separation distances between conductive parts below the values in Table 3.

For measurement of creepage distance and clearance, the principles shown in Figure J.4 shall be applied.



Key

1 Terminal

2 Metal

3 Coating

4 Separation distance before coating

5 Clearance ━━━━

6 Creepage distance ▪▪▪▪▪▪

Figure J.4 – Description

In visual inspection, the coating of the capacitor including the coated part of terminals shall not have any cracks or defects exposing internal live parts or in defined insulated or coated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

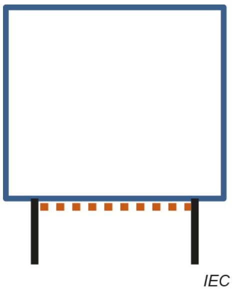
J.2 Measurement

J.2.1 Creepage distance between terminals

J.2.1.1 Cased style

The coating of terminals at the bottom side of cased capacitors normally is not specified. In that case, the creepage distance is set equal to the clearance, although following the bottom surface of the capacitor it can be a longer distance. See Figure J.5.

If the insulation of terminals at the bottom side of the capacitor is specified, the creepage distance shall be determined according to the requirements of the relevant safety standard.



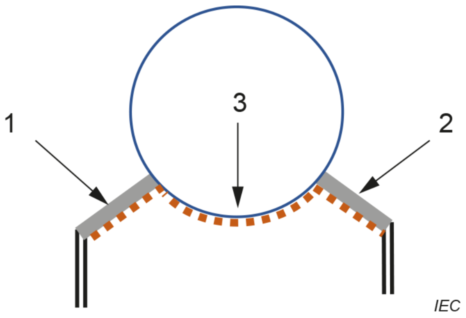
Key

▪▪▪▪▪ Creepage distance

Figure J.5 – Creepage distance – cased style

J.2.1.2 Conformal coated style

Creepage distance is the shortest distance along the surface of a solid insulating material between two conductive parts. It starts and ends at the end of conductive part of the leads. See Figure J.6.



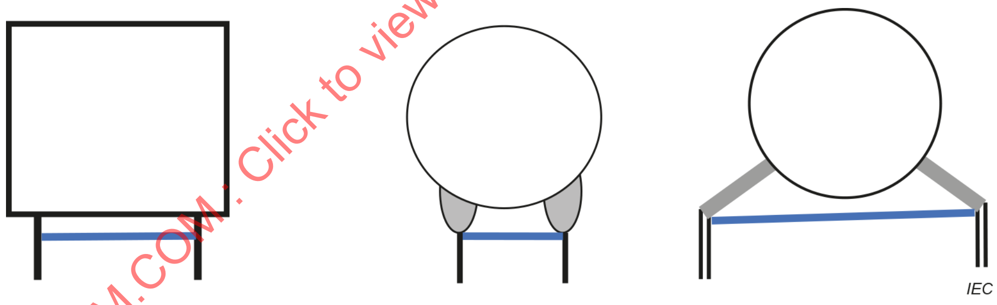
Key

1, 2	Grey area – coating on lead wires (solid insulation, not conductive)
3	Separation distance before coating (arc length)
▪▪▪▪▪	Creepage distance

Figure J.6 – Creepage distance – conformal coated style

J.2.2 Clearance between terminals

The clearance is the distance in air between the uncoated terminals. As the breakdown strength of the lead wire coating is tested by the voltage proof test (5.3.1, Test A), it fulfils the requirements to the capacitor body insulation between the terminals. See J.1.3 for additional explanation. Figure J.7 illustrates the clearance for different component constructions.



Key

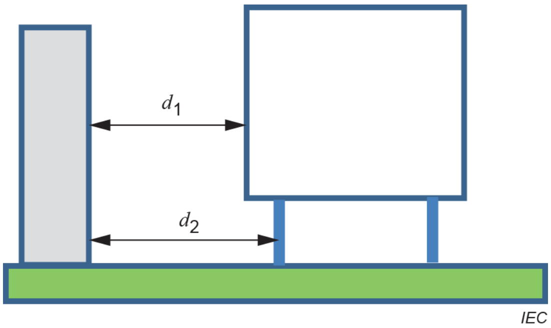
▬	Clearance

Figure J.7 – Clearance between terminals

J.2.3 Clearance in mounted stage

J.2.3.1 Cased style

For cased style capacitors, the definition of clearances in mounted stage is shown in Figure J.8. For requirements, see J.2.3.3.



Key:

d_1 Minimum distance between capacitor body and conductive parts

d_2 Minimum distance between capacitor terminals and conductive parts

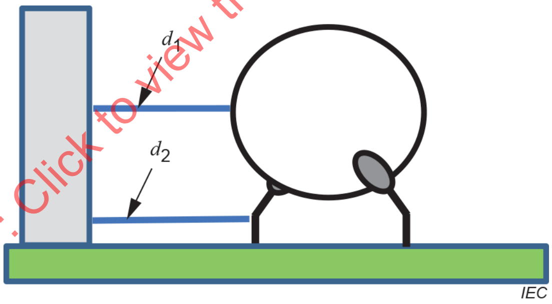
Figure J.8 – Clearance in mounted stage – cased style

J.2.3.2 Conformal coated style

If the insulation of leads (between lead wire and the outside of coating) is not specified and checked to comply with the requirements, it shall not be considered as double/reinforced or basic insulation. Additional insulation to other conductive parts is needed if the distance is less than the clearance required by the relevant safety standard.

To determine the clearance, two cases shall be distinguished:

1) Capacitor body larger than lead pitch – Figure J.9
2) Capacitor body smaller than lead pitch – Figure J.10



Key

d_1 Clearance between body and a conductive part

d_2 Clearance between terminal and a conductive part

Figure J.9 – Clearance – capacitor body larger than lead pitch

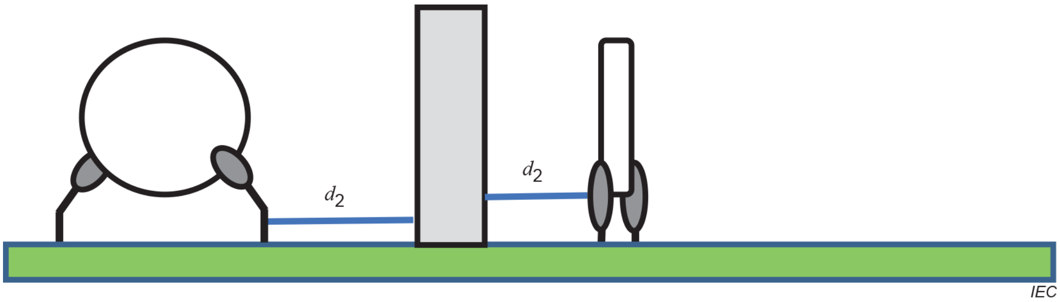


Figure J.10 – Clearance – capacitor body smaller than lead pitch

J.2.3.3 Requirements

The minimum distance d_1 may become "0" if the capacitor body coating complies to the required insulation level.

The minimum distance d_2 shall fulfil the requirements to clearances as given in the relevant safety standard.

Additional insulation (e.g., sleeve) shall be added if double or reinforced insulation is required and the minimum distance cannot be kept.

J.2.4 Conductors between terminals

Uncoated conductors or other conductive parts positioned underneath the capacitors are allowed, provided the design complies with the minimum creepage distance and clearance requirements. Otherwise, protective coating of the conductive parts is required, which complies with the relevant requirements to additional protective insulation.

A conductor between the terminals of a capacitor bridging double or reinforced insulation shall be coated with a suitable coating material complying with the requirements to double or reinforced insulation. For further information see IEC 60664-3.

J.3 Precautions in handling

Housing of conformal coated capacitors shall not be user accessible or exposed to undue mechanical stress, which could degrade the insulating properties of the housing material.

The coated part of lead wires shall be protected against bending (e.g., by clamping using a suitable tool) if the lead wires are formed before or during assembly to a board (e.g., kinking).

Annex K
(normative)

Safety and performance tests qualification approval

K.1 Overview

It is possible to qualify the products to cover wider range of parameters than the safety related ones. This annex describes the sampling plan, test schedule, sampling plan for lot-by-lot test and periodical testing for this wider qualification.

K.2 Qualification approval

Table K.1, Table K.2 and Table K.3 shall be used when qualification approval is sought.

The procedures for qualification approval testing are given in the generic specification, IEC 60384-1:~~2008~~2021, Q.2, in which Q.2.4 refers to lot-by-lot and periodic inspections. The schedules to be used for qualification approval testing on the basis of lot-by-lot and periodic inspections are given in 8.5 and Table K.4 of this document. The schedule to be used for qualification approval testing based on fixed sample sizes in accordance with IEC 60384-1:~~2008~~2021, Q.2.4, is given in 8.4.3, Table K.1 and Table K.2 of this document. For the two procedures, the sample sizes and the number of permissible nonconforming items shall be of comparable order. The test conditions and requirements shall be the same. Qualification approval according to the fixed sample sizes of Table K.1 and Table K.2 is preferred.

Table ~~4~~ K.1 – Sampling plan – Safety and performance tests qualification approval – Assessment level DZ

Group	Test	Subclause of this document	Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass ~~Per group~~ ~~DZ~~
0	Visual examination	5.2	~~50~~ 52 + 12[d] +	0[a]
	Dimensions (gauging)	5.2	6[e] +	
	Capacitance	5.3.2	6 to 18[h]	
	Resistance	5.3.4	+24	
	Tangent of loss angle[g]	5.3.3		
	Voltage proof	5.3.1		
	Insulation resistance	5.3.5		
	Spares		20 + 6[f]	
1A	Dimensions (detail)	5.2	6	0[a]
	Robustness of terminations	5.4		
	Resistance to soldering heat	5.5		
	Component solvent resistance	5.20		
1B	Solderability	5.6	12	0[a]
	Solvent resistance of the marking	5.21		

Group	Test	Subclause of this document	Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass ~~Per group~~ ~~DZ~~
	Rapid change of temperature	5.7		
	Vibration	5.8		
	Bump or shock[f]	5.9 or 5.10		
1	Container sealing [c] Climatic sequence	5.11 5.12	18	0
2	Damp heat, steady state	5.13	~~10~~ 12	0[a]
3	Impulse voltage Endurance Class X and RC units Class Y and RC units Lead-through[i]	5.14 5.15 5.15.5 5.15.6 5.15.7	12[d] 12[d] 6[e]	0[a]
4	Charge and discharge[b]	5.16	6	0[a]
5	Radiofrequency characteristics	5.17	4	0[a]
6	Passive flammability	5.18	6 to 18[h]	0
7	Active flammability	5.19	24	0

Tests in Group 0 can be made in any practical order, except for ceramic capacitors the capacitance value shall be measured first.

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] If applicable.

[c] If required in the detail specification.

[d] If multi-section capacitors consisting of X- and Y-capacitors are to be tested, 12 specimens shall be taken for the tests on the X-capacitors and 12 other specimens for the tests on the Y-capacitors.

[e] Additional capacitors if lead-through capacitors are tested.

[f] Whichever is ~~prescribed~~ stated in the detail specification.

[g] Not required for RC units, or for capacitors other than those of metallized film or metallized paper construction.

[h] The smallest, a medium (in the case of more than four case sizes) and the largest case size shall be tested. Of each case size, three specimens of the maximum capacitance and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.

[i] Attention is drawn to the option of carrying out a combined voltage/current test as ~~prescribed~~ stated in 5.15.7.

Table ~~5~~ K.2 – Test schedule and sampling plan for lot-by-lot tests

Safety and performance tests qualification approval – Assessment level DZ			
Group	**Clause number and test referred to Clause 5 of this document**	**Inspection level IL**	**Acceptance number [b]**
A1	5.2 Visual examination 5.2 Dimensions (gauging)	S-4	0
A2	5.3.2 Capacitance 5.3.4 Resistance [a] 5.3.3 Tangent of loss angle (metallized film and ~~ceramic~~ paper capacitors only) 5.3.1 Voltage proof (Test A) 5.3.5 Insulation resistance (Test A)	I	0
B1	5.6 Solderability [a]	S-3	0

[a] If applicable.

[b] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample, and then no further nonconforming items are permitted.

Table ~~7~~ K.3 – Test schedule for safety and performance tests qualification approval Assessment level DZ

Subclause number and test [a]	**Conditions of test [a]**	***n* and *c* [b]**	**Performance requirements [a]**
Group 0	**Non-destructive**	See Table K.1	
5.2 Visual examination			No visible damage Legible marking and as specified in the detail specification
5.2 Dimensions (gauging)			See detail specification
5.2.2 Creepage distances and clearances			See detail specification and Table 3
5.3.2 Capacitance			Within specified tolerance
5.3.4 Resistance (if applicable)			Within specified tolerance
5.3.3 Tangent of loss angle (metallized film and ~~ceramic~~ paper capacitors only)	Frequency: …		See detail specification
5.3.1 Voltage proof	Method: …		No permanent break-down or flashover
5.3.5 Insulation resistance	Method: …		See Table 6

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements [a]
Group 1A	**Destructive**	See Table K.1	
5.2 Dimensions (detail)			See detail specification and Table 13
5.4 Robustness of terminations	Severity: see detail specification		No visible damage
5.5 Resistance to soldering heat (if applicable)	No pre-drying See detail specification for the Method 1		
5.20 Component solvent resistance (if applicable)	Solvent: … Solvent temperature: … Method 2		See detail specification
	Recovery: …		
5.5.3 Final measurements	Visual examination		No visible damage
	Capacitance		See Table 7
	Resistance (if applicable)		See Table 7
Group 1B	**Destructive**	See Table K.1	
5.6 Solderability (if applicable)	Without ageing For method see detail specification		Good tinning as evidenced by free flowing of the solder with wetting of the terminations or solder shall flow within 3 s, as applicable.
5.21 Solvent resistance of the marking	Solvent: … Solvent temperature: … Method 1 Rubbing material: cotton wool		Legible marking
	Recovery: …		
5.7 Rapid change of temperature	T_A = Lower category temperature T_B = Upper category temperature Five cycles Duration t_1 = 30 min		
5.7.2 Final inspection	Visual examination		No visible damage
5.8 Vibration	For mounting method and severity: see detail specification		
5.7.2 Final inspection	Visual examination		No visible damage
5.9 Bump (repetitive shock) or 5.10 Shock	For mounting method and severity: see detail specification		
5.9.3 or 5.10.3 Final measurements	Visual examination		No visible damage
	Capacitance		See 5.9.3 or 5.10.3
	Resistance (if applicable)		See Table 9

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements [a]
Group 1	**Destructive**	See Table K.1	
5.11 Container sealing (if applicable)	Test Qc or Test Qd of IEC 60068-2-17 as prescribed in the detail specification		No evidence of leakage
5.12 Climatic sequence			
5.12.2 Initial measurements	Measurements made in 5.5.3, 5.9.3 or 5.10.3 as appropriate		
5.12.3 Dry heat	Temperature: upper category temperature Duration: 16 h		
5.12.4 Damp heat, cyclic, test Db, first cycle			
5.12.5 Cold	Temperature: lower category temperature Duration: 2 h		
5.12.6 Damp heat, cyclic, test Db, remaining cycles			
5.12.7 Final measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 9
	Resistance (if applicable)		See Table 9
	Tan δ (if applicable)		See Table 9
	Voltage proof		See Table 9
	Insulation resistance		See Table 9
Group 2	**Destructive**	See Table K.1	
5.13 Damp heat, steady state			
5.13.2 Initial measurements	Group 0 measurements to be used		
5.13.3 Test conditions	Ceramic capacitors: half of the sample with U_R applied; the other half with no voltage applied Other capacitors: no voltage applied		
5.13.4 Final measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 10 and Table 11
	Resistance (if applicable)		~~See Table 15~~"-
	Tan δ (if applicable)		~~See Table 15~~"-
	Voltage proof		~~See Table 15~~"-
	Insulation resistance		~~See Table 15~~"-

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements [a]
Group 3	**Destructive**	See Table K.1	
5.14.2 Initial measurements	Group 0 measurements to be used		
5.14 Impulse voltage	3 pulses, full wave ~~Number of impulses: 24 max.~~ Peak voltage: ... V, see Table 1 and Table 2		See 5.14.3 and 5.14.4
5.15 Endurance	Duration: 1 000 h		
	Voltage, current and temperature: see 5.15.4, 5.15.5, 5.15.6 and 5.15.7		
5.15.8 Final measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 12
	Resistance (if applicable)		See Table 12
	Tan δ (if applicable)		See Table 12
	Voltage proof		See Table 12
	Insulation resistance		See Table 12
Group 4	**Destructive**	See Table K.1	
5.16 Charge and discharge	Only for metallized and ceramic capacitors and RC units using such capacitors		
5.16.2 Initial measurements	Group 0 measurements may be used, provided the measuring conditions are the same as required for this test; in addition, except for RC units, tan δ shall be measured at: 10 kHz for $C_N \leq 1$ µF 1 kHz for $C_N > 1$ µF		
5.16.4 Final measurements	Capacitance		See Table 13
	tan δ at same frequency as initial measurement (not for RC units)		See Table 13
	Resistance (if applicable)		See Table 13
	Insulation resistance		See Table 13
Group 5	**Non-destructive**	See Table K.1	See detail specification
5.17 Radiofrequency characteristics	If required in the detail specification; see detail specification for measuring method		
Group 6	**Destructive**	See Table K.1	See 5.18.1
5.18 Passive flammability			
Group 7	**Destructive**	See Table K.1	See 5.19.3
5.19 Active flammability			

Tests in Group 0 can be made in any practical order, except for ceramic capacitors the capacitance value shall be measured first

[a] Subclause numbers of test conditions and requirements refer to Clause 5.

[b] n = number of specimens, c = number of permissible nonconforming items.

[c] When, for a ceramic capacitor, a precise measurement of capacitance drift is required, preconditioning in accordance with Annex G should be performed as advised by the manufacturer.

K.3 Quality conformance inspection

K.3.1 General

In addition to 8.5, the content of K.3.2, K.3.3 and K.3.4 shall be followed:

K.3.2 Groups A and B inspection

These tests shall be carried out on a lot-by-lot basis according to Table K.4.

For Group B tests, the inspection lot shall consist of components produced with similar processes and materials, according to the test concerned.

K.3.3 Group C inspection

To maintain the qualification, the qualification approval tests shall be carried out on a periodic basis.

The samples to be submitted to the periodic test in Table K.4 shall be representative of the current production of the specified periods and shall be taken from the same rated voltage, class, and subclass. In subsequent periods, other case sizes in production shall be tested with the aim of covering the whole range of the approval.

No nonconforming items are permitted for Class Y capacitors in the voltage proof test.

K.3.4 Test schedule for qualification approval

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in the relevant blank detail specification, for example, IEC 60384-14-1.

Table ~~8~~ K.4 – Assessment level

	DZ		
Inspection subgroup [b]	**IL**	**Acceptance number**	
A1	S-4	0	
A2	I	0	
B1	S-3	0	
Inspection subgroup [b]	**DZ**		
	p	n	c [a]
C1A	6	6	0
C1B ~~[c]~~	6	12	0
C1	6	18	0
C2	6	12	0
C3:			
Class X	3	12	0
Class Y	3	12	0
Lead-through	3	6	0
C4	6	6	0
C5	12	4	0
C6	12	6 to18	0
C7	12	24	0

The sampling sizes corresponding to inspection levels should be selected from IEC 61193-2:2007, Table 1.

IL = inspection level

p = periodicity in months

n = sample size

c = permissible number of nonconforming items

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] The content of the inspection subgroups is described in the relevant blank detail specification.

[c] The vibration, bump and shock tests in this subgroup are required to be carried out every 12 months only.

Annex X
(informative)

Cross-references to the previous edition of this document

The revision of this sectional specification has resulted in a new structure. Table X.1 and Table X.2 provide cross-references for all references to specific elements of the previous edition of this sectional specification.

Table X.1 – Reference to IEC 60384-14 for clause/subclause or annex

IEC 60384-14:2013 + AMD1:2016 4.1st edition Clause/Subclause or Annex	IEC 60384-1:20xx 5th edition Clause/Subclause or Annex	Notes
1 1.1 to 1.2	1	Scope and Object are merged into one in accordance with the ISO/IEC Directives Part 2
1.3	2	In accordance with ISO/IEC Directives Part 2
1.4	7 7.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
1.4.1 to 1.4.3	7.2 to 7.4	In accordance with the change of clause numbers
1.4.4	6	This clause is merged into one
1.5	3.1	In accordance with ISO/IEC Directives Part 2
1.6	6 6.1 to 6.2	In accordance with the change of clause numbers. The hanging paragrah is avoided in accordance with ISO/IEC Directives Part 2.
1.6.1 to 1.6.3	6.3 to 6.5	In accordance with the change of clause numbers
1.7	3.2	In accordance with the change of clause numbers
1.7.1 to 1.7.2	3.2.1 to 3.2.2	In accordance with the change of clause numbers
2	4	In accordance with the change of clause numbers
2.1 to 2.3	4.1 to 4.3	In accordance with the change of clause numbers
3	8	In accordance with the change of clause numbers
3.1 to 3.4	8.1 to 8.4	In accordance with the change of clause numbers
3.4.2	Annex K	Text transferred to Annex K
3.5	8.5 8.5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
3.5.1 to 3.5.4	8.5.2 to 8.5.4	In accordance with the change of clause numbers
3.5.1.1	8.5.2.1 and K.3.2	Text modified and original copied to K.3.2
3.5.1.2	K.2.3	Text transferred to Annex K
3.5.2.2	K.3.4	Text transferred to Annex K
4	5 5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.1	5.2 5.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2	5.3	In accordance with the change of clause numbers

IEC 60384-14:2013 + AMD1:2016 4.1st edition Clause/Subclause or Annex	IEC 60384-1:20xx 5th edition Clause/Subclause or Annex	Notes
4.2.1	5.3.1 5.3.1.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2.1.1 to 4.2.1.4	5.3.1.2 to 5.3.1.5	In accordance with the change of clause numbers
4.2.2	5.3.2 5.3.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2.2.1 to 4.2.2.2	5.3.2.2 to 5.3.2.3	In accordance with the change of clause numbers
4.2.3 to 4.2.4	5.3.3 to 5.3.4	In accordance with the change of clause numbers
4.2.5	5.3.5 5.3.5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2.5.1 to 4.2.5.2	5.3.5.2 to 5.3.5.3	In accordance with the change of clause numbers
4.3	5.4	In accordance with the change of clause numbers
4.4	5.5 6.5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.4.1 to 4.4.2	5.5.2 to 5.5.3	In accordance with the change of clause numbers
4.5	5.6 5.6.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.5.1 to 4.5.2	5.6.2 to 5.6.3	In accordance with the change of clause numbers
4.6	5.7 5.7.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.6.1	5.7.2	In accordance with the change of clause numbers
4.7	5.8 5.8.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.7.1 to 4.7.2	5.8.2 to 5.8.3	In accordance with the change of clause numbers
4.8	5.9 5.9.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.8.1 to 4.8.2	5.9.2 to 5.9.3	In accordance with the change of clause numbers
4.9	5.10 5.10.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.9.1 to 4.9.2	5.10.2 to 5.10.3	In accordance with the change of clause numbers
4.10	5.11 5.11.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.10.1 to 4.10.2	5.11.2 to 5.11.3	In accordance with the change of clause numbers
4.11	5.12 5.12.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.11.1 to 4.11.6	5.12.2 to 5.12.7	In accordance with the change of clause numbers

IEC 60384-14:2013 + AMD1:2016 4.1st edition **Clause/Subclause or Annex**	**IEC 60384-1:20xx 5th edition** **Clause/Subclause or Annex**	**Notes**
4.12	5.13 5.13.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.12.1 to 4.12.3	5.13.2 to 5.13.4	In accordance with the change of clause numbers
4.13	5.14 5.14.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.13.1 to 4.13.3	5.14.2 to 5.14.4	In accordance with the change of clause numbers
4.14	5.15 5.15.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.14.1	5.15.2 5.15.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.14.1.1	5.15.2.2	In accordance with the change of clause numbers
4.14.2 to 4.14.7	5.15.3 to 5.15.8	In accordance with the change of clause numbers
4.15	5.16 5.16.1	In accordance with the change of clause numbers. The hanging paragrah is avoided in accordance with ISO/IEC Directives Part 2.
4.15.1 to 4.15.3	5.16.2 to 5.16.4	In accordance with the change of clause numbers
4.16 to 4.17	5.17 to 5.18	In accordance with the change of clause numbers
4.17.1	5.18.1 5.18.1.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.17.1.1	5.18.1.2	In accordance with the change of clause numbers
4.17.2	5.18.2 5.18.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.17.2.1 to 4.17.2.2	5.18.2.2 to 5.18.2.3	In accordance with the change of clause numbers
4.18 to 4.20	5.19 to 5.21	In accordance with the change of clause numbers
Annex A to Annex I	Annex A to Annex I	No change
-	Annex J	New annex
3.4.2	Annnex K	New annex

Table X.2 indicates the new figure and table numbers with respect to IEC 60384-14:2013 + AMD1:2016 (4.1st edition).

Table X.2 – Reference to IEC 60384-14 for figure/table

IEC 60384-14:2013 + AMD1:2016 4.1st edition Figure/Table	IEC 60384-14:20xx 5th edition Figure/Table	Notes
Figure 1 to Figure 5	Figure 1 to Figure 5	No change
Figure 6	Figure 9	In accordance with the change of clause numbers
Figure 7 to Figure 9	Figure 6 to Figure 8	In accordance with the change of clause numbers
Table 3	Table 14	In accordance with the change of clause numbers
Table 4	Table K.1	Transferred to Annex K
Table 5 upper part	Table 15	Renumbered according to formation of Annex K
Table 5 lower part	Table K.2	Transferred to Annex K
Table 6	Table 16	Renumbered following the formation of Annex K
Table 7	Table K.3	Transferred to Annex K
Table 8	Table 17 and Table K4	Doubled in Annex K and renumbered following the formation of Annex K
–	Table 8	Unnumbered table numbered
Table 9 to Table 13	Table 3 to Table 7	In accordance with the change of clause numbers
Table 14 and Table 15	Table 9 and Table 10	In accordance with the change of clause numbers
-	Table 11	New table
Table 16 and Table 17	Table 12 and Table 13	In accordance with the change of clause numbers

Bibliography

IEC 60050-151, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-581, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

IEC 60065:2014, *Audio, video, and similar electronic apparatus – Safety requirements*

IEC 60335-1, *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60384-14-1, *Fixed capacitors for use in electronic equipment – Part 14-1: Blank detail specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains – Assessment level DZ*

~~IEC 60384-14-3, *Fixed capacitors for use in electronic equipment – Part 14-3: Blank detail specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains – Assessment level DZ*~~

IEC 60417, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

IEC 60939-3:2015, *Passive filter units for electromagnetic interference suppression – Part 3: Passive filter units for which safety tests are appropriate*

IEC 60940, *Guidance information on the application of capacitors, resistors, inductors and complete filter units for electromagnetic interference suppression*

IEC 60950-1:2013, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 62368-1:2018, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*
IEC 62368-1:2018/COR1:2020

K.W. Plessner, Ageing of the Dielectric Properties of Barium Titanate Ceramics. *Proceedings of the Physical Society*, Section B, Volume 69, Issue 12, pp. 1261 to 1268~~ (1956)~~

List of comments

1 The scope is now making clear that this document is primarily intended for components connected to AC mains, but they can with given conditions also be used in DC supplies.

2 This definition is added to support the Annex H information.

3 This statement is made to reaffirm the information already given in Table 2 above. This information has not been clear for all users of this standard.

4 The number of supply systems has increased and subsequently the number of rated voltage values of capacitors in the marketplace has multiplied. It is very difficult to give a preferred list of values, and the general rules given is Subclause 4.2.3 are sufficient in defining these values.

5 The requirement for tape is separated from other insulations.

6 Through this new edition the importance of the mechanical integrity of the component insulation is underlined.

7 Following the discussions with IEC TC 108, Annex J is added to describe in detail different capacitor styles, and how the creepage and clearance distances are measured.

In this context the importance of the mechanical integrity of the components is raised to focus.

8 This is clarifying the test voltage for capacitors, which are qualified for DC applications. This was not clear in the previous edition of this document.

9 The importance of the mechanical integrity after several tests is emphasized, which was not so clear in the previous edition. This kind of new requirement is added to many following tests.

10 The comments in Table 6 are repeated here in case that Table 5 is cited out of context.

11 This prevents unnecessary duplication of testing when more severe test conditions are followed.

12 The DHSS test is made more severe than it was in the previous edition. The additional test with voltage aims to offer a better guarantee than before to screen out marginal designs, especially when the capacitor designs are getting smaller and smaller.

13 This is a new requirements table for DHSS test with voltage. The requirements are somewhat relaxed from the requirements in the test without voltage but according to good industrial practise. The electrical requirements in Table 11 are same as in Table I.1 in Annex I defining the specific humidity robustness grades.

14 Table 12 is put here to help the reader to understand how many pieces shall be tested in different tests / test combinations.

15 This gives the reasoning why the Y1 capacitors are not tested in active flammability test. The field experience from long period of time supports that active flammability is not a problem for Y1 capacitors.

16 This document is primarily for safety components and their qualification. It can be used also for performance testing, but this qualification test program is moved to normative Annex K.

17 There is support from the field experience that in some demanding applications the value of tangent of loss angle of metallized film and paper capacitors may be growing to critical levels. This measurement, and measurements after critical tests, is added as a precaution to guarantee more robust designs of capacitors in demanding applications.

18 Annex E is editorially rearranged but the contents has not been changed from the previous edition.

19 This is a new requirement from the previous edition to clarify when the rated DC voltage shall be defined.

20 The test descriptions and requirements are collected from subclauses of I.2 to new Clause I.3 to avoid tautology and for clarity.

21 This new Annex J is added to give description how creepage distance and clearance are measured for different capacitor styles, and clearance between capacitors and conductive parts in mounted stage. The questions of insulation are discussed, both on components and on conductors near the components.

IEC 60384-14

Edition 5.0 2023-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour
inside

Fixed capacitors for use in electronic equipment –
Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

Condensateurs fixes utilisés dans les équipements électroniques –
Partie 14: Spécification intermédiaire – Condensateurs fixes pour la suppression des interférences électromagnétiques et la connexion au réseau d’alimentation

IEC 60384-14:2023-01(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

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IEC 60384-14 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2013 and Amendment 1:2016. This edition constitutes a technical revision.

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

a) in damp heat steady state test, all capacitor types are tested both with and without rated voltage; the number of test pieces has been increased;

b) tangent of loss angle is added In Group 0 tests, in safety tests only;

c) qualification approval based on safety and performance tests has been removed from the main text to a normative annex;

d) the range of rated voltages is given instead of exact rated voltage values;

e) normative annex for description of capacitor styles and of creepage/clearance distance measurement has been added;

f) the importance of mechanical failures (cracks) in component encapsulation as a safety feature is highlighted in handling instructions and requirements after all relevant tests.

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

Draft	Report on voting
40/2985/FDIS	40/3022/RVD

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

The language used for the development of this International Standard is English.

A list of all the parts of the IEC 60384 series, published under the general title *Fixed capacitors for use in electronic equipment,* can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains

1 Scope

This part of IEC 60384 applies to capacitors and resistor-capacitor combinations intended to be connected to AC mains or other supply with a nominal voltage not exceeding 1 000 V AC (RMS), and with a nominal frequency not exceeding 100 Hz. This document includes also additional specific conditions and requirements for the connection to DC supplies with a rated voltage not exceeding 1 500 V DC.

The principal object of this part of IEC 60384 is to prescribe preferred ratings and characteristics and to select, from IEC 60384-1, the appropriate quality assessment procedures, tests and measuring methods and to give general performance requirements for this type of capacitor. Test severities and requirements prescribed in detail specifications referring to this sectional specification are of equal or higher performance level; lower performance levels are not permitted.

This document also provides a schedule of safety tests to be used by national testing stations in countries where approval by such stations is required.

The overvoltage categories in combination with the AC mains voltages for the capacitors classified in this document are to be taken from IEC 60664-1.

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 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60063, *Preferred number series for resistors and capacitors*

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-17, *Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing*

IEC 60384-1:2021, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

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

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 61193-2:2007, *Quality assessment systems – Part 2: Selection and use of sampling plans for inspection of electronic components and packages*

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

CISPR 17, *Methods of measurement of the suppression characteristics of passive EMC filtering devices*

ISO 7000, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

3 Terms and definitions and classification

3.1 Terms and definitions

For the purposes of this document, the terms, and definitions of IEC 60384-1, as well as the following, apply.

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

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

NOTE Some definitions of IEC 60384-1 have been expanded, as is indicated by a note.

3.1.1
AC capacitor
capacitor designed essentially for application with a power-frequency alternating voltage

Note 1 to entry: AC capacitors may be used on DC supplies having the same voltage as the AC RMS rated voltage of the capacitor. For use of capacitors with rated DC voltage greater than the rated AC voltage, see Annex H.

3.1.2
electromagnetic interference suppression capacitor
radio interference suppression capacitor
AC capacitor used for the reduction of electromagnetic interference caused by electrical or electronic apparatus, or other sources

3.1.3
capacitor of Class X
RC unit of Class X
capacitor or RC unit of a type suitable for use in situations where failure of the capacitor or RC unit would not lead to danger of electrical shock but could result in a risk of fire

3.1.4
capacitor of Class Y
RC unit of Class Y
capacitor or RC unit of a type suitable for use in situations where failure of the capacitor could lead to danger of electric shock

3.1.5
two-terminal capacitor
electromagnetic interference suppression capacitor having two terminals

Note 1 to entry: See Figure 1.

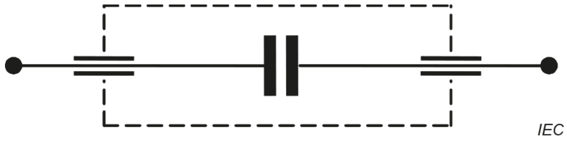


Figure 1 – Two-terminal EMI suppression capacitor

3.1.6
series RC unit

functional combination of a resistor in series with a capacitor of Class X or Y

Note 1 to entry: See Figure 2.

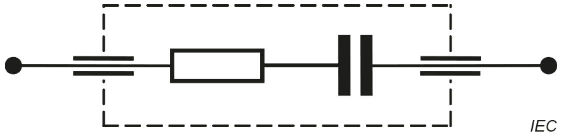


Figure 2 – RC unit

Note 2 to entry: In this document, where the word "capacitor" appears, the words "capacitor or RC unit" should be understood where the context permits.

3.1.7
lead-through capacitor

<coaxial> capacitor with a central current-carrying conductor surrounded by a capacitor element which is symmetrically bonded to the central conductor and to the outer casing to form a coaxial construction

Note 1 to entry: These lead-through capacitors are coaxially mounted (see Figure 3).

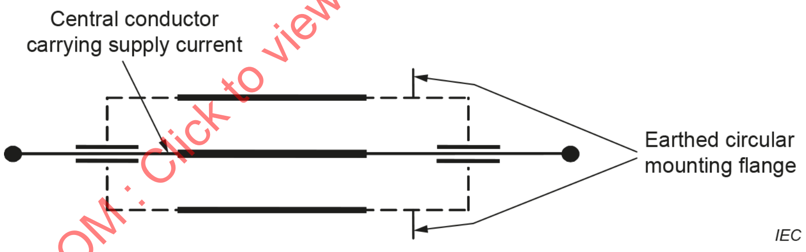
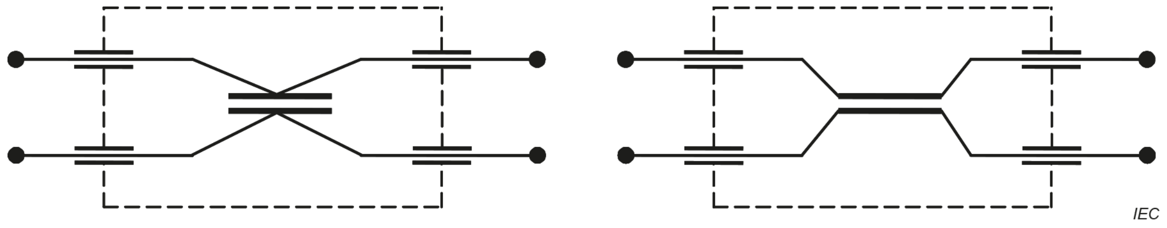


Figure 3 – Lead-through capacitor (coaxial)

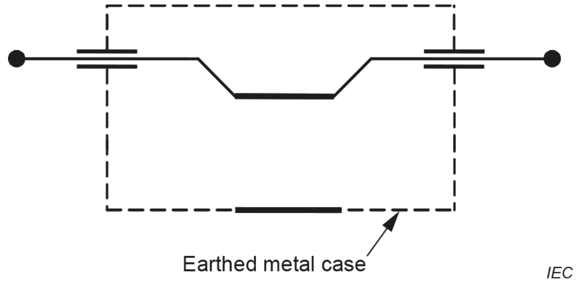
3.1.8
lead-through capacitor

<non-coaxial> capacitor in which the supply currents flow through or across the electrodes

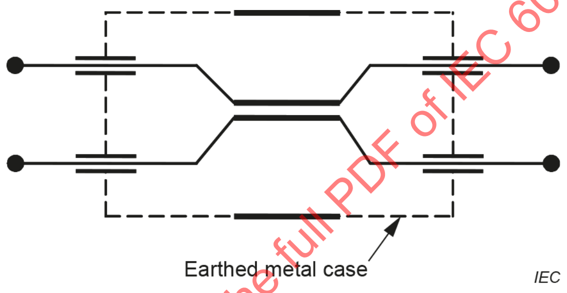
Note 1 to entry: See Figure 4 a), Figure 4 b), Figure 4 c) and Figure 4 d).



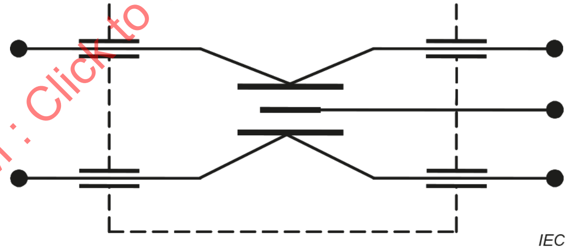
a) Lead-through capacitor for symmetrical use (non-coaxial)



b) Lead-through capacitor for asymmetrical use (non-coaxial)



c) Multiple unit lead-through capacitor (non-coaxial) for symmetrical and asymmetrical use



d) Multiple unit lead-through capacitor

Figure 4 – Lead-through capacitors

3.1.9
by-pass capacitor

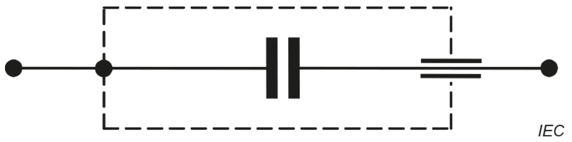
capacitor where radiofrequency interference currents are by-passed

Note 1 to entry: There are three common forms: single, delta and T-connected. The single capacitor consists of a capacitor in a metal case with one termination connected to the case as in Figure 5 a); the delta form consists of an X-capacitor and two Y2-capacitors arranged in a delta network as in Figure 5 b); the T-connected form consists of three capacitors C_A, C_B and C_C connected in T as shown in Figure 5 c).

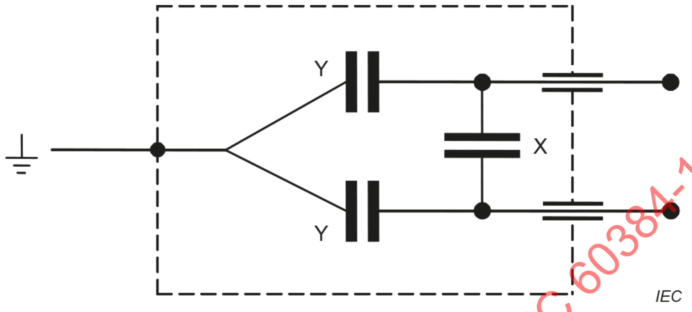
The delta and T-connected forms are electrically equivalent (star-delta transformation). In the T-connected form the X-capacitor is the result of the series connection of $C_B – C_C$ and the Y-capacitors are the results of the series connections of $C_A – C_B$ and $C_A – C_C$.

When T-connected capacitors are submitted to tests, and it is stated that voltages shall be applied across the X-capacitors, such voltages shall be applied between the line (L) and neutral (N) terminations. Similarly, when it is stated that voltages shall be applied across the Y-capacitors, such voltages shall be applied between the line and neutral terminations connected together and the earth termination.

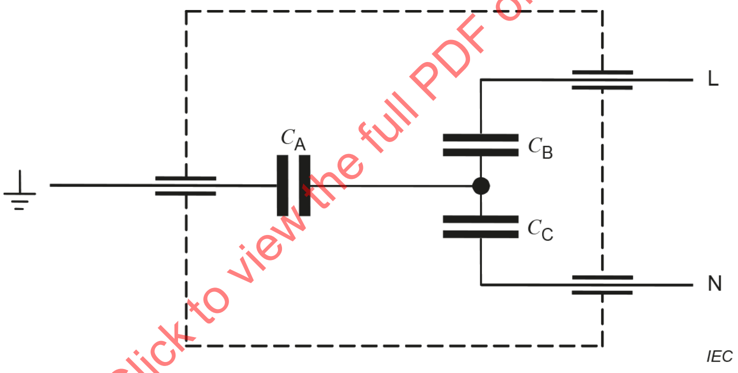
Note 2 to entry: See Figure 5a), Figure 5b) and Figure 5c)



a) Single by-pass capacitor



b) Delta by-pass capacitor (in metallic housing)



c) Example of a T-connected by-pass capacitor (in non-metallic housing)

NOTE For capacitors with non-metallic housings, the earth connection is brought out as a separate termination as is shown in Figure 5c).

Figure 5 – By-pass capacitors

3.1.10
rated voltage

<for capacitor> RMS operating voltage of rated frequency or the DC operating voltage that can be applied continuously to the terminations of a capacitor at any temperature between the lower and the upper category temperatures

Note 1 to entry: This implies, for capacitors covered by this document, that the category voltage is the same as the rated voltage.

3.1.11
rated DC voltage
U_R DC

maximum DC operating voltage, which can be applied continuously to the terminations of a capacitor at any temperature between the lower and the upper category temperatures

Note 1 to entry: This term and designation (U_R DC) are used only for a capacitor specified with rated DC voltage exceeding its rated AC voltage (RMS).

3.1.12
rated power
<of a series RC unit> maximum power that can be dissipated by the RC unit at the rated temperature during continuous operation

3.1.13
upper category temperature
maximum surface temperature for which the capacitor has been designed to operate continuously

Note 1 to entry: For lead-through capacitors and series RC units, the external surface temperature can be affected by internal heating due to the lead-through current. The terminations of a capacitor are considered to be part of the external surface.

Note 2 to entry: This definition replaces that given in IEC 60384-1:2021, 3.41, because suppression capacitors in accordance with this document are intended to be connected to the mains network and can have internal heat generation as a result.

3.1.14
lower category temperature
minimum surface temperature for which the capacitor has been designed to operate continuously

Note 1 to entry: This definition replaces that given in IEC 60384-1:2021, 3.10.

3.1.15
rated temperature
<of a lead-through capacitor or series RC unit> maximum ambient temperature at which a lead-through capacitor can carry its rated lead-through current or a series RC unit can dissipate its rated power

Note 1 to entry: This definition replaces that given in IEC 60384-1:2021, 3.24.

3.1.16
insertion loss
<for capacitors> ratio of the voltage before and after the insertion of the suppressor as measured at the terminations

Note 1 to entry: When measured in decibels, the insertion loss is 20 times the logarithm to base 10 of the ratio stated.

3.1.17
rated current of the conductor
<of a lead-through capacitor> maximum permissible current flowing through the conductors of the capacitor at the rated temperature during continuous operation

3.1.18
main resonant frequency
<of a two-terminal capacitor> lowest frequency at which the impedance of the capacitor is a minimum when applying a sinusoidal voltage

3.1.19
impulse voltage
periodic transient voltage of a defined waveform as described in IEC 60060-1

3.1.20
passive flammability
ability of a capacitor to burn with a flame as a consequence of the application of an external source of heat

3.1.21
active flammability

ability of a capacitor to burn with a flame as a consequence of electric loading

3.1.22
surface mount capacitor

capacitor whose small dimensions and nature of shape of terminations make it suitable for surface mounting in hybrid circuits and on printed boards

3.2 Classifications

3.2.1 Classification of X capacitors

Class X capacitors are divided into two subclasses (see Table 1) according to the peak voltage of the impulses superimposed on the mains voltage to which they may be subjected in service. Such impulses can arise from lightning strikes on outside lines, from switching in neighbouring equipment, or switching in the equipment in which the capacitor is used.

Table 1 – Classification of Class X capacitors

Subclass	Peak impulse voltage in service	Application	Peak impulse voltage U_P applied before endurance test	
			$C_N \le 1,0$ µF	$C_N > 1,0$ µF
X1	>2,5 kV ≤4,0 kV	High pulse application	4 kV	$U_P = \frac{4}{\sqrt{\frac{C_N}{10^{-6}\ \mathrm{F}}}}$ in kV
X2	≤2,5 kV	General purpose	2,5 kV	$U_P = \frac{2,5}{\sqrt{\frac{C_N}{10^{-6}\ \mathrm{F}}}}$ in kV

X1 capacitors may be substituted by Y2 or Y1 capacitors of the same or higher U_R. X2 capacitors can be substituted with X1 or Y2 or Y1 capacitors of the same or higher U_R.

NOTE 1 The factor used for the reduction of U_P for capacitance values above 1,0 µF maintains 0,5 × $C_N U_P^2$ constant for these capacitance values; C_N is in F.

NOTE 2 Overvoltage categories in association with rated impulse voltage and rated mains voltage are found in IEC 60664-1.

3.2.2 Classification of Y capacitors

Class Y capacitors are further divided into three subclasses, Y1, Y2 and Y4, as shown in Table 2.

Table 2 – Classification of Class Y capacitors

Subclass	Type of insulation bridged	Range of rated voltages	Peak impulse voltage U_P applied before endurance test	
Y1	Double insulation or reinforced insulation	≤500 V	8,0 kV	
Y2	Basic insulation or supplementary insulation	≥150 V ≤500 V	$C_N \le 1,0$ µF	$C_N > 1,0$ µF
			5 kV	$U_P = \frac{5}{\sqrt{\frac{C_N}{10^{-6}\ \mathrm{F}}}}$ kV
Y4	Basic insulation or supplementary insulation	<150 V	2,5 kV	

Y2 capacitors may be substituted by Y1 capacitors of the same or higher U_R.

NOTE 1 For definitions of basic, supplementary, double, and reinforced insulation, see IEC 61140.

NOTE 2 The factor used for the reduction of U_P for capacitance values above 1,0 µF maintains 0,5 × $C_N U_P^2$ constant for these capacitance values; C_N is in F.

NOTE 3 Overvoltage categories in association with rated impulse voltage and rated mains voltage are found in IEC 60664-1.

One Y1-capacitor may bridge double insulation or reinforced insulation.

The enclosure of a Y1-capacitor shall not contain other components.

Assemblies, like Delta by-pass or T-connected by-pass capacitors, may be constructed from Y-capacitors and X-capacitors provided these capacitors fulfil the requirements for the relevant X and Y subclasses.

One Y-capacitor may bridge basic insulation. One Y-capacitor may bridge supplementary insulation. If combined basic and supplementary insulations are bridged by two or more Y2- or Y4-capacitors in series, they shall have the same class and sub-class, the same rated voltage, and the same nominal capacitance value.

4 Preferred ratings and characteristics

4.1 Preferred climatic categories

The values given in detail specifications should be selected from this paragraph.

The capacitors covered by this document are classified into climatic categories according to the general rules given in IEC 60068-1:2013, Annex A.

The lower and upper category temperatures and the duration of the damp heat, steady state test shall be chosen from the following:

- lower category temperature: −65 °C, −55 °C, −40 °C, −25 °C and −10 °C;
- upper category temperature: +85 °C, +100 °C, +105 °C, +110°C, +125 °C and +155 °C;
- duration of the damp heat, steady state test: 21 days and 56 days.

The severities for the cold and dry heat tests are the lower and upper category temperatures, respectively.

For guidance on the application of the categories described above, see IEC 60940:2015.

4.2 Preferred values of ratings

4.2.1 Nominal capacitance (C_N)

The preferred values of nominal capacitance are:

1; 1,5; 2,2; 3,3; 4,7; 6,8 and their decimal multiples.

These values conform to the E6 series of preferred values given in IEC 60063.

4.2.2 Tolerance on nominal capacitance

The maximum tolerance on nominal capacitance is ±20 %.

4.2.3 Selection of rated voltages (U_R)

The range of rated AC voltages is from 125 V to 1 000 V.

The range of rated DC voltages is from 125 V to 1 500 V.

Electromagnetic interference suppression capacitors should be chosen to have a rated voltage equal to, or greater than, the nominal voltage of the supply system to which they are connected. The design of the capacitors shall take into account the possibility that the voltage of the system can rise by up to 10 % above the system's nominal voltage. In star connections, the maximum voltage over the capacitors shall be calculated in the worst possible case when the nominal capacitance tolerances of the capacitors used are considered.

4.2.4 Nominal resistance (R_N)

Preferred values of nominal resistance shall be taken from the E6 series of IEC 60063.

4.2.5 Rated temperature

The rated temperature for lead-through capacitors and series RC units shall be not less than +40 °C.

4.2.6 Passive flammability

The preferred category of passive flammability permitted is Category B (see 5.18). If category C is used, it shall be agreed between the component supplier and the customer. See 5.18 also for alternative passive flammability testing.

Exemption: for components smaller than 1 750 mm^3, the passive flammability category C is permitted.

NOTE Passive flammability categories better than C can require flame retardant additives, which can be considered to cause environmental impact. These categories are subject to discussion between manufacturers and customers to find a compromise between safety and environmental requirements.

4.3 Requirements for sleeving, tape, tubing and wire insulation

Sleeving, tape, tubing, and wire insulation used in the components falling under this document shall be rated for the voltage involved and the temperature attained under any condition of actual use. Sleeving, tubing and wire insulation shall have flame retardant rating Class VW1. Tape shall be flame retardant.

If insulated terminals are requested, the preferable colours should be transparent or white.

5 Test and measurement procedures, and performance requirements

5.1 General

This clause supplements the information given in IEC 60384-1:2021, from Clause 4 to Clause 10.

AC tests carried out at a frequency between 50 Hz and 100 Hz are considered valid for any nominal frequency between 50 Hz and 100 Hz. In case of doubt, 50 Hz shall be the reference frequency for measurements.

During handling, testing and inspection, unintended damages to the insulation on component body and leads shall be avoided. The handling instructions as provided by the manufacturer shall be followed.

5.2 Visual examination and check of dimensions

5.2.1 General

See IEC 60384-1:2021, 7.1 with the additional details in 5.2.2.

5.2.2 Creepage distances and clearances

Creepage distances and clearances on the outside of the capacitor between live parts of different polarity or between live parts and a metal case shall be not less than the appropriate values given in Table 3.

Table 3 is based on IEC 60664-1, but equipment safety standards IEC 60335-1 and IEC 62368-1 have also been considered. Further information can be obtained from IEC 60664-1.

Table 3 is generated using the following environmental conditions as main guideline:

Pollution degree 2, altitude ≤ 2 000 m and CTI (Comparative Tracking Index) of materials ≥ 100.

The creepage distances smaller than those in Table 3 can be used, if rules given in IEC 60664-1 for CTI of materials in components allow that. Creepage distance shall always be larger or equal to the clearance distance indicated in this table. Equipment standards can require larger distances than ones given here.

Compliance shall be checked by measurement in accordance with the rules laid down in IEC 60664-1 for measurements on the outside of the capacitor. Additional requirements can be necessary, for example for capacitors intended to be used in other environments than pollution degree 2 (e.g. drip-proof and splash-proof capacitors) or for the use of capacitors in altitudes higher than 2 000 m. See IEC 60664-1 for guidance.

Table 3 – Creepage distances and clearances

Points of measurement	**Rated voltage (RMS)**									
	$U_R \le 130$ V		130 V < $U_R \le 250$ V		250 V < $U_R \le 500$ V		500 V < $U_R \le 760$ V		760 V < $U_R \le 1\,000$ V	
	Creepage distance mm	**Clearance** mm	**Creepage distance** mm	**Clearance** mm	**Creepage distance** mm	**Clearance** mm	**Creepage distance** mm	**Clearance** mm	**Creepage distance** mm	**Clearance** mm
Between live parts of different polarity (functional insulation) [a]	2,0	1,5	3,0	2,5	4,0	3,0	6,3	5,5	8,0	5,5
Between live parts and other metal parts over basic insulation [b]	2,0	1,5	4,0	3,0	5,0	4,0	6,3	5,5	8,0	7,5
Between live parts and other metal parts over reinforced insulation [c]	8,0	8,0	8,0	8,0	10,0	8,0	12,6	11,0	16,0	11,0

NOTE The reinforced insulation figures for voltages >500 V are given for information only. In this standard Y1 capacitors are limited to 500 V.

[a] These limits shall be used for measurements between terminals of an X-capacitor.

[b] These limits shall be used for measurements between each terminal and the metal case of an X-capacitor and for measurements between terminals or between each terminal and the metal case of an Y2- or Y4-capacitor.

[c] These limits shall be used for measurements between terminals of an Y1- capacitor (up to 500 V).

Annex J describes different styles of capacitors, and how the creepage and clearance distances are measured for them. Precautions required for handling the capacitors, for example when the leads are bent, are also described.

5.3 Electrical tests

5.3.1 Voltage proof

5.3.1.1 General

See IEC 60384-1:2021, 6.2 with the details from 5.3.1.2 to 5.3.1.5.

5.3.1.2 Test circuit for DC tests

Omit the capacitor C_1 if the capacitor under test, or a section of it, is a metallized film or metallized paper capacitor.

The product of R_1 and (C_1 + C_X) shall be less than, or equal to, 1 s and greater than 0,01 s.

R_1 includes the internal resistance of the power supply.

R_2 shall limit the discharge current to a value equal to, or less than, 0,05 A.

5.3.1.3 Test circuit and method for AC tests

When a 50/60 Hz voltage is applied for qualification approval and periodic tests, the voltage shall be supplied from a transformer fed from a variable autotransformer, and the voltage shall be raised from near zero to the test voltage at a rate not exceeding 150 V/s. The test time shall be counted from the time the test voltage is reached. At the end of the test time, the test voltage shall be reduced to near zero and the capacitor discharged through a suitable resistor.

For lot-by-lot and 100 % testing, the voltage shall be applied directly at the full test voltage, but overvoltage peaks should be avoided.

5.3.1.4 Applied voltage

The voltages of Table 4 shall be applied between the respective measuring points shown in IEC 60384-1:2021, Table 3, for a period of 1 min for qualification approval and periodic testing and for a period of not less than 1 s for lot-by-lot quality conformance testing, with the following details:

a) the test in accordance with 2c of IEC 60384-1:2021, Table 3, shall not be carried out;

b) for encapsulated units with a non-metallic case, a voltage proof test such as Test C shall be carried out only for qualification approval tests and periodic tests;

c) the method of applying the test voltage for Test C shall be given in the detail specification. For qualification testing, the foil method given in IEC 60384-1:2021, 6.2.3.4. shall be used, unless otherwise specified in the detail specification;

   NOTE This test is applicable only to insulated capacitors in non-metallic case or in insulated metallic case. See IEC 60384-1:2021, 6.6.3.4.

d) for testing during a period between 1 s and 2 s, the voltage of Table 4 shall be increased as indicated in Figure 9;

e) when a capacitor is qualified for DC applications in accordance with Annex H, the test voltage as calculated in accordance with Table H.1 for the voltage proof test A shall be applied for lot-by-lot (100 %) tests and qualification tests, if its value is higher than the value as determined in accordance with Table 4.

Attention is drawn to the fact that repetition of the voltage proof test by the user can damage the capacitor. If repetition of the voltage proof test is made by the user, the applied voltage should not be greater than 66 % of the test voltage specified in Table 4.

Table 4 – Voltage proof

Class	Range of rated voltages	Test A[d]	Test B or Test C
X1 X2	≤ 1 000 V	4,3 U_R (DC) [c]	2 U_R + 1 500 V (AC) with a minimum of 2 000 V (AC) [a]
Y1	≤ 500 V	4 000 V (AC)	4 000 V (AC)
Y2	≥ 150 V ≤ 500 V	U_R + 1 200 V (AC) with a minimum of 1 500 V (AC) [b]	2 U_R + 1 500 V (AC) with a minimum of 2 000 V (AC) [b]
Y4	< 150 V	900 V (AC) [b]	900 V (AC) [b]

[a] For Delta and T-connected capacitor units in accordance with Figure 5b and Figure 5c, the test voltage for terminals to case shall be the appropriate test voltage for the Y-capacitors.

[b] For lot-by-lot tests of Class Y2- and Y4-capacitors, the AC test voltage may be replaced by a DC voltage of 1,5 times the prescribed AC voltage.

[c] The U_R in this DC test is the rated AC voltage value.

[d] For capacitors qualified in accordance with Annex H, see 5.3.1.4 e).

5.3.1.5 Requirements

There shall be no permanent breakdown or flashover during the test period.

NOTE The occurrence of self-healing breakdowns during the application of the test voltages on metalized film capacitors is allowed.

In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.3.2 Capacitance

5.3.2.1 General

See IEC 60384-1:2021, 6.3 with the details in 5.3.2.2 and 5.3.2.3.

5.3.2.2 Measuring conditions

The capacitance measured shall be the series equivalent capacitance.

The measuring frequency shall be 1 kHz, but the measuring frequency shall be 1 MHz for ceramic capacitors with C_N < 100 pF (class 2) and C_N ≤ 1 000 pF (class 1).

The measuring temperature shall be in accordance with IEC 60384-1:2021, 5.2.1.

The measuring voltage shall not exceed the rated voltage. For ceramic capacitors, the measuring voltage shall be 1,0 V ± 0,2 V.

As the nominal capacitance of ceramic capacitors, as measured above, is the small-signal capacitance, the manufacturer shall supply the following information for ceramic capacitors:

a) the maximum expected 50/60 Hz current through the capacitor at rated voltage taking into account capacitance tolerance and temperature characteristic (or coefficient) of capacitance;
b) the minimum expected capacitance taking into account the capacitance tolerance and temperature characteristic (or coefficient) of capacitance.

5.3.2.3 Requirements

The capacitance value shall be within the specified tolerance.

5.3.3 Tangent of loss angle

This test is normally required for metallized and ceramic capacitors only.

See IEC 60384-1:2021, 6.4 with the following details:

The measuring frequency shall be 10 kHz for C_N ≤ 1 µF and 1 kHz for C_N > 1 µF. For ceramic capacitors, the measuring frequency shall be 1 kHz, but for capacitors with C_N < 100 pF (class 2) and C_N ≤ 1 000 pF (class 1), the measuring frequency shall be 1 MHz.

5.3.4 Resistance (Equivalent Series Resistance (ESR)) (for RC units only)

The ESR shall be measured in a series equivalent circuit at the following frequency:

100 kHz for $R_N \times C_N < 50$ µs;

1 kHz for $R_N \times C_N \geq 50$ µs

where

R_N is the nominal resistance in ohms, and

C_N is the nominal capacitance in farads.

5.3.5 Insulation resistance

5.3.5.1 General

See IEC 60384-1:2021, 6.1 with the details in 5.3.5.2 and 5.3.5.3.

In lot-by-lot quality conformance testing, the measuring may be interrupted at the time that the value of the insulation resistance exceeds the limits of Table 5 or Table 6, which can be shorter than 60 s.

5.3.5.2 Temperature correction

When stated in the detail specification, the temperature at which the measurement is made shall be noted. If this temperature differs from 20 °C, a correction shall be made to the measured value by multiplying it by the appropriate correction factor stated in the sectional specification for the relevant dielectric or that given in the detail specification.

5.3.5.3 Requirements

The insulation resistance shall exceed the values of Table 5 or Table 6, as appropriate.

Table 5 – Insulation resistance – Safety tests only

Test A		**Test B or Test C**
When C_N > 0,33 µF RC_N in s	When C_N ≤ 0,33 µF R in MΩ	R in MΩ
2 000 [a, b]	6 000	6 000

- C_N is the nominal capacitance and R the measured insulation resistance.
- Limits more severe and related to the dielectric may be given in the detail specification for performance tests only, where possible by reference to the appropriate IEC publication.
- For capacitors having one termination connected to the case, the insulation resistance limits for Test A should be used.

  For capacitors with a discharge resistor, measurement should be carried out with the discharge resistor disconnected. If the resistor cannot be disconnected without the capacitor being destroyed, the test should be omitted in Group A; and, for qualification approval and periodic tests, the test should be carried out on half of the specimens in the sample, which should consist of capacitors specially made without discharge resistors.

[a] Also for mixed plastic/paper dielectrics.

[b] For capacitors with ester-impregnated paper dielectric, the values of the table shall be replaced respectively by the values 500, 1 500 and 2 000.

Table 6 – Insulation resistance – Safety and performance tests

Dielectric	Test A		Test B or Test C
	When C_N > 0,33 µF RC_N in s	When C_N ≤ 0,33 µF R in MΩ	R in MΩ
Paper [a, b]	2 000	6 000	6 000
Plastic	5 000	15 000	30 000
Ceramic	–	6 000	3 000

- C_N is the nominal capacitance and R the measured insulation resistance.
- Limits more severe and related to the dielectric may be given in the detail specification for performance tests only, where possible by reference to the appropriate IEC publication.
- For capacitors having one termination connected to the case, the insulation resistance limits for Test A should be used.
- For capacitors with a discharge resistor, measurement should be carried out with the discharge resistor disconnected. If the resistor cannot be disconnected without the capacitor being destroyed, the test should be omitted in Group A; and, for qualification approval and periodic tests, the test should be carried out on half of the specimens in the sample, which should consist of capacitors specially made without discharge resistors.

[a] Also for mixed plastic/paper dielectrics.

[b] For capacitors with ester-impregnated paper dielectric, the values of the table shall be replaced respectively by the values 500, 1 500 and 2 000.

5.4 Robustness of terminations

See IEC 60384-1:2021, 7.3 with the following details.

The test method and degree of severity to be used shall be specified in the detail specification.

The test for snap-in contacts shall be specified in the detail specification; the test methods and severity shall comply with the applicable clauses of IEC 61210.

The test shall be carefully conducted in accordance with the instructions so that the coating of the capacitor is not broken due to mishandling of the part. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.5 Resistance to soldering heat

5.5.1 General

This test is not applicable to capacitors with insulated leads longer than 10 mm, or to capacitors with terminations not intended to be soldered (such as screw and fast-on terminations).

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

See IEC 60384-1:2021, 9.1 with the details in 5.5.2 and 5.5.3.

5.5.2 Test conditions

There shall be no pre-drying.

5.5.3 Final inspection, measurements, and requirements

The final measurements after this test are the intermediate measurements after the tests of Subgroup 1A and before the remainder of the tests of Group 1. The capacitors shall be visually examined and measured and shall meet the requirements of Table 7.

Table 7 – Resistance to soldering heat – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
Capacitance	5.3.2	The difference between the capacitance measured finally and in Group 0 of Table 14, or Table 15 shall not exceed 5 % [a]
Resistance (if applicable)	5.3.4	$\lvert \Delta R/R \rvert$ ≤ 5 %
[a] For ceramic capacitors, the capacitance difference shall not exceed 10 %.		

5.6 Solderability

5.6.1 General

This test is not applicable to capacitors with terminations not intended for soldering (such as screw terminations and snap-in contacts).

See IEC 60384-1:2021, 9.2 with the details in 5.6.2 and 5.6.3.

5.6.2 Test conditions

No ageing is required.

Preferred solders and their solder bath temperature and process time:

- Sn96,5Ag3Cu,5 solder: 245 °C ± 3 °C for (3 ± 0,3) s;
- Sn99,3Cu,7 solder: 250 °C ± 3 °C for (3 ± 0,3) s.

When Method 2 is used, a soldering iron of size A shall be used.

5.6.3 Requirements

See Table K.3.

5.7 Rapid change of temperature

5.7.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

See IEC 60384-1:2021, 8.1 with the following details.

- Number of cycles: 5.
- Duration of exposure at the temperature limits: minimum 30 min.

5.7.2 Final inspection

In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.8 Vibration

5.8.1 General

See IEC 60384-1:2021, 7.4 with the details in 5.8.2 and 5.8.3.

5.8.2 Test conditions

The following degree of severity of test Fc applies: 0,75 mm displacement or 100 m/s^2, whichever is the lower amplitude, over one of the following frequency ranges: 10 Hz to 55 Hz, 10 Hz to 500 Hz, 10 Hz to 2 000 Hz. The total duration shall be 6 h.

The detail specification shall prescribe the frequency range and shall also prescribe the mounting method to be used. For capacitors with axial leads that are intended to be mounted by the leads, the distance between the body and the mounting point shall be 6 mm ± 1 mm.

5.8.3 Final inspection

In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

5.9 Repetitive shock (bump)

5.9.1 General

The detail specification shall state whether the bump or the shock test applies.

See IEC 60384-1:2021, 7.5 with the details in 5.9.2 and 5.9.3.

5.9.2 Test conditions

The following are the preferred severities.

- Total number of bumps: 1 000 or 4 000
- Acceleration: 400 m/s^2
- Pulse duration: 6 ms

The mounting method and the severity shall be specified in the detail specification.

5.9.3 Final inspection, measurements, and requirements

The final measurements after this test are the intermediate measurements after the tests of Subgroup 1B and before the remainder of the tests of Group 1.

The capacitors shall be visually examined and measured and shall meet the following requirements.

- There shall be no visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
- The change of capacitance compared with the value measured in Group 0 of Table K.3 shall not exceed 5 %, except for ceramic capacitors for which it shall not exceed 10 %.
- The value of tan δ shall not exceed the limit stated in the detail specification.
- The change of resistance (if applicable) shall not exceed the limit in Table 9.

When preconditioning is performed, initial measurements for reference shall be carried out after preconditioning.

5.10 Shock

5.10.1 General

The detail specification shall state whether the bump or the shock test applies.

See IEC 60384-1:2021, 7.6 with the details in 5.10.2 and 5.10.3.

5.10.2 Test conditions

The severities in Table 8 are preferred.

Pulse-shape: half-sine wave

Table 8 – Shock test preferred severities

Peak acceleration m/s^2	**Corresponding duration of the pulse** ms
500	11
1 000	6

The mounting method, the severity, and the number of shocks along each axis shall be specified in the detail specification.

5.10.3 Final inspection, measurements, and requirements

The final measurements after this test are the intermediate measurements after the tests of Subgroup 1B and before the remainder of the tests of Group 1.

The capacitors shall be visually examined and measured and shall meet the following requirements.

- There shall be no visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
- The change of capacitance compared with the value measured in Group 0 of Table K.3 shall not exceed 5 %, except for ceramic capacitors for which it shall not exceed 10 %.
- The value of tan δ shall not exceed the limit stated in the detail specification.
- The change of resistance (if applicable) shall not exceed the limit in Table 9.

When preconditioning is performed, initial measurements for reference shall be carried out after preconditioning.

5.11 Container sealing

5.11.1 General

This test is applicable only if prescribed in the detail specification.

See IEC 60384-1:2021, 7.9 with the details in 5.11.2 and 5.11.3.

5.11.2 Test conditions

The capacitors shall be subjected to either Test Qc or to Test Qd of IEC 60068-2-17, as appropriate. Unless otherwise specified in the detail specification, Method 1 shall be used when Test Qc is employed.

5.11.3 Requirements

During or after the test, as applicable, there shall be no evidence of leakage.

5.12 Climatic sequence

5.12.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

See IEC 60384-1:2021, 8.2 with the details from 5.12.2 to 5.12.7.

5.12.2 Initial measurements

The initial measurements for the climatic sequence are the measurements carried out in 5.5.3, 5.9.3 or 5.10.3 as appropriate.

5.12.3 Dry heat

See IEC 60384-1:2021, 8.2.3 with the following details.

No measurements are required at the upper category temperature.

5.12.4 Damp heat, cyclic, test Db, first cycle

See IEC 60384-1:2021, 8.2.4.

5.12.5 Cold

See IEC 60384-1:2021, 8.2.5 with the following details.

No measurements are required at the lower category temperature.

5.12.6 Damp heat, cyclic, test Db, remaining cycles

See IEC 60384-1:2021, 8.2.7.

5.12.7 Final inspection, measurements, and requirements

See IEC 60384-1:2021, 8.2.8 with the following details.

Recovery shall be for 24 h ± 2 h under standard atmospheric conditions for testing.

After recovery, the capacitors shall be visually examined and measured and shall meet the requirements of Table 9.

Table 9 – Climatic sequence – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	The final capacitance value shall be within 5 %[a] of the value measured in 5.5.3, 5.9.3 or 5.10.3 as applicable
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,008 for $C_N \leq 1$ µF 0,005 for $C_N > 1$ µF
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage given in Table 4 No permanent breakdown or flashover is permitted
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors, the capacitance difference shall not exceed 10 %.

5.13 Damp heat, steady state (DHSS)

5.13.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

Annex I describes specific humidity robustness grades, tests, and requirements for applications, where high stability under high humidity operating conditions is required. A sample tested to comply to one of the robustness grades of Annex I fulfils the requirements of the second half of the sample described in 5.13.3 (DHSS with voltage applied), and the test results are valid for approval testing in accordance with 8.4, Annex F or Annex K.

See IEC 60384-1:2021, 8.3 with the details from 5.13.2 to 5.13.4.

5.13.2 Initial measurements

Initial measurements have been carried out in Group 0 of Table 14 or Table 15.

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

5.13.3 Test conditions

The sample shall be divided to two parts of equal size.

The first half of the sample shall be tested without voltage applied with following preferred severities:

- Temperature: 40 °C ± 2 °C;
- Relative humidity: (93 ± 3) %;
- Duration: 21 days or 56 days, in line with the climatic category of the capacitor.

The other half of the sample shall be tested with rated AC voltage applied in the following conditions:

- Temperature: 40 °C ± 2 °C;
- Relative humidity: (93 ± 3) %;
- Duration: 21 days.

5.13.4 Final inspection, measurements, and requirements

Recovery shall be for 1 h to 2 h under standard atmospheric conditions for testing.

After recovery, the capacitors tested without voltage shall be visually examined and measured and shall meet the requirements of Table 10.

After recovery, the capacitors tested with voltage shall be visually examined and measured and shall meet the requirements of Table 11. The electrical requirements of Table 11 are identical to those of Table I.1.

Table 10 – Damp heat, steady state –
Requirements for samples tested without voltage applied

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	The final capacitance value shall be within 5 %[a] of the value measured in Group 0 of Table 16 or Table K.3, as applicable
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,008 for $C_N \leq 1$ µF 0,005 for $C_N > 1$ µF
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage as in Table 4 No permanent breakdown or flashover is permitted
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors the capacitance difference shall not exceed 15 %.

Table 11 – Damp heat, steady state – Requirements for samples tested with voltage applied

Measurement	Measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	Metalized capacitors: $\lvert \Delta C \rvert$ ≤ 10 % Ceramic capacitors: $\lvert \Delta C \rvert$ ≤ 15 %
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,024 for C_N ≤ 1 µF [a] 0,015 for C_N > 1 µF [a]
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Voltage proof	5.3.1	Test voltage as in Table 4
Insulation resistance	5.3.5	> 50 % of the applicable limits of Table 5 or Table 6, or minimum 200 MΩ, whichever is higher

The change of capacitance value depends on technology, and, as is for example the case for ceramic capacitors, can be reversible. Thus, the requirements are different.

[a] For certain applications, smaller values for the increase tan δ can be required.

5.13.5 Sample size summary for humidity tests

Table 12 shows sample sizes for humidity tests in accordance with 5.13, Annex H and Annex I.

Table 12 – Sample sizes for humidity tests

DHSS Test group	Without voltage	U_R AC applied	U_R DC applied
5.13	6	6[b]	
Annex H, Table H.1	+ 0	+ 0	+ 6[a]
Annex I, Grade (I), (II), (III)	+ 0	10	+ 6[a]

NOTE The + sign in front of the numbers means an additional sample to the samples of 5.13.

[a] Additional sample if the capacitors are also specified for U_R DC exceeding U_R AC (RMS)

[b] See 5.13.1

5.14 Impulse voltage

5.14.1 General

This test is to be carried out as a sequence with the endurance test described in 5.15.

5.14.2 Initial measurements

Initial measurements have been made in Group 0 of Table 17 or Table K.3.

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

5.14.3 Test conditions

Each individual capacitor shall be subjected to a maximum of 24 impulses of the same polarity. The time between impulses shall be not less than 10 s. The peak value of the voltage impulse shall be as given in Table 1 and Table 2.

The rise time, t_r, is defined as $t_r = (t_{90} - t_{30}) \times 1{,}67$. Time t_r is the front time T_1 defined in IEC 60060-1:2010, 7.1.18.

The decay time t_d is the same as time to half value T_2 defined in IEC 60060-1:2010, 7.1.22.

The waveform will be determined by the test circuit parameters. Details of the test circuit are given in Annex A.

Before use, the functioning of the circuit shall be checked using C_X values of 0,01 µF and 0,1 µF and the values for the other circuit elements as given in Table A.1. The rise time t_r and decay time t_d shall be within 0 % + 50 % of the values given in Table A.2. The capacitors C_X used for this check should not be high-permittivity ceramic.

If the waveform from the check shows a damped oscillation, the peak-to-peak value of this oscillation, U_{pp}, shall be not greater than 10 % of the peak voltage of the impulse U_{CR} as shown in Figure 6.

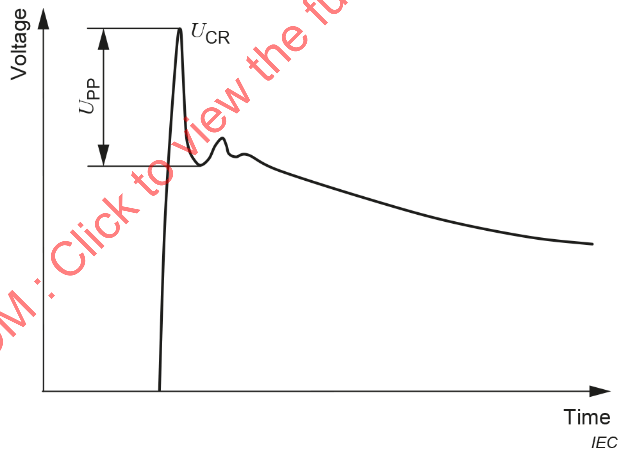


Figure 6 – Impulse wave form

5.14.4 Requirements

There shall be no permanent breakdown or flashover.

If any three successive impulses are shown by the oscilloscope monitor to have had a waveform indicating that no self-healing breakdowns or flashovers have taken place in the capacitor, then no further impulses shall be applied, and the capacitor shall be counted as conforming.

If all 24 impulses have been applied to the capacitor and 3 or more of them are of a waveform indicating that no self-healing breakdowns or flashovers have occurred, then the capacitor shall be counted as conforming, but, if fewer than three impulses are of the required waveform, then the capacitor shall be counted as a nonconforming item.

5.15 Endurance

5.15.1 General

When, for fixed capacitors of ceramic dielectric Class 2, a precise measurement of capacitance drift is required, preconditioning should be performed as advised by the manufacturer (see Annex G).

The endurance test shall be started within one week of the completion of the impulse voltage test. See IEC 60384-1:2021, 8.5 with the details from 5.15.2 to 5.15.9.

5.15.2 Test conditions

The capacitors shall be placed in the test chamber in such a manner that no capacitor is within 25 mm of any other capacitor.

However, there is an exception, when the width or diameter of the capacitor is less than 25 mm, then the distance between the capacitors may be reduced to the value of this width or diameter, provided that this causes no extra heating of the capacitors. If in doubt, the 25 mm spacing shall be used.

The capacitors shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from exceeding ±3 °C of the specified temperature at any point where capacitors are placed.

For non-self-healing capacitors, a 1 A fuse or larger, if the capacitance value under test so requires, shall be connected in the supply circuit, and shall not rupture during the test.

For self-healing capacitors, a fuse or other device of suitable sensitivity may be connected in the circuit of each capacitor to indicate if a failure occurs.

5.15.3 Sampling

The sample for the endurance test shall be divided, if necessary, into two or three parts according to the numbers given in Table 15, Table K.1, Table 17, or Table K.3, so that separate tests can be carried out on the X-capacitors, the Y-capacitors, and the lead-through arrangements.

For example, when testing delta capacitor units (see 3.1.9), 12 capacitor units shall be tested according to 5.15.5 and another 12 units according to 5.15.6. When testing a Class Y lead-through capacitor (see 3.1.8), 12 capacitors shall be tested in accordance with 5.15.6 and six units in accordance with 5.15.7.

5.15.4 Initial measurements

Initial measurements have been carried out in 5.14.2.

5.15.5 Endurance for Class X capacitors and RC units containing Class X capacitors

For multi-section capacitors, all X-sections shall be tested in parallel, if necessary, by shorting out any Y-sections. For T-connected capacitors (see 3.1.9), the test shall be carried out between the terminals normally connected to line and neutral.

The capacitors and RC units, for which no rated temperature is given, shall be submitted to an endurance test of 1 000 h at upper category temperature at a voltage of 1,25 U_R, except that once every hour, the voltage shall be increased to voltage U_S RMS for 0,1 s, where $U_S = 1{,}5 \times U_R$ or 1 000 V RMS, whichever is higher. Each of these voltages shall be applied to each capacitor individually through a resistor of 47 Ω, with a tolerance of ±5 %. The suitable circuit is shown in Annex B.

The value of this resistor is chosen to simulate the high-frequency impedance of the supply mains. For capacitors with capacitance value above 10 µF, the dissipated power in the resistor becomes large. With increasing capacitance values the dissipated power may rise to unpractical level. In this kind of situation, safety test houses may allow a lower resistance value of 5 % of the reactance value of the test capacitor C_x to be used.

RC units, for which a rated temperature is given, shall be mounted in the manner specified by the manufacturer, and the oven shall be stabilized at the rated temperature without voltage applied to the capacitors. The voltage shall then be switched on and the time counted from this moment.

After thermal stability due to internal heating of the resistor has been re-established, the case temperature of one of the capacitors shall be measured. It shall not exceed the upper category temperature.

The test circuit should be designed so that voltage transients and current surges are avoided during switching. This may be achieved by discharging the capacitor before switching to the new voltage provided that the total time taken to change over to U_S RMS and back does not exceed 30 s.

5.15.6 Endurance for Class Y capacitors and RC units containing Class Y capacitors

For multi-section capacitors, all Y-sections shall be tested in parallel, if necessary, by shorting out any X-sections. For T-connected capacitors (see 3.1.9), the terminals normally connected to line and neutral shall be shorted and the test shall be carried out between them, and the terminal normally connected to earth.

The capacitors shall be submitted to an endurance test of 1 000 h at an upper category temperature at a voltage of 1,7 U_R, except that once every hour the voltage shall be increased to voltage U_S RMS for 0,1 s, where U_S = 1 000 V RMS. Each of these voltages shall be applied to each capacitor individually through a resistor of 47 Ω with a tolerance of ±5 %. The test circuit is shown in Annex B.

The test circuit should be designed so that voltage transients and current surges are avoided during switching. This may be achieved by discharging the capacitor before switching to the new voltage provided that the total time taken to change over the U_S RMS and back does not exceed 30 s.

5.15.7 Endurance for the lead-through arrangements

In addition to the endurance tests of the capacitors in accordance with 5.15.5 and 5.15.6, the current-carrying capacity of the lead-through arrangements shall be tested. All the lead-through wires shall be connected in series and the capacitors submitted to an endurance test of 1 000 h with a current of 1,1 I_R passing through the lead-through wires. During this test, no voltage is applied to the capacitor dielectric.

The capacitors shall be mounted in the manner specified by the manufacturer, and the oven shall be stabilized at the rated temperature without current passing through the capacitors. The current shall then be switched on and the time counted from this moment.

After thermal stability has been re-established, the case temperature of one of the capacitors shall be measured. It shall not exceed the upper category temperature.

5.15.8 Test conditions – Combined voltage/current tests

For some types of capacitors, such as coaxial lead-through capacitors, it is possible without difficulty to apply both test voltage and current to the capacitor at the same time. If prescribed in the detail specification, a combined endurance test of 1 000 h may be carried out instead of the tests of 5.15.5 (or 5.15.6) and 5.15.7 by using the number of specimens appropriate for the test of 5.15.5 (or 5.15.6) and 1,1 times the rated current flowing through the lead-through arrangements.

The case temperature of one of the capacitors shall be measured as in 5.15.7. It shall not exceed the upper category temperature.

5.15.9 Final inspection, measurements, and requirements

The capacitors shall be visually examined and measured in the order given in Table 13.

Table 13 – Endurance – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured).
Capacitance	5.3.2	The final capacitance value shall be within 10 % [a] of the value in Group 0 of Table 15 or Table K.1 as applicable
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,008 for $C_N \le 1$ µF 0,005 for $C_N > 1$ µF
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \le 10$ %
Voltage proof	5.3.1	Test voltage as in Table 4 No permanent breakdown or flashover is permitted
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors the capacitance difference shall not exceed 20 %.

5.16 Charge and discharge

5.16.1 General

This test is applicable only to metallized capacitors, ceramic capacitors and RC units using such capacitors.

See IEC 60384-1:2021, 6.11 with the details from 5.16.2 to 5.16.4.

5.16.2 Initial measurements

Initial measurements have been made in Group 0 of Table 15 or Table K.1. In addition, except for RC units, tan δ shall be measured in accordance with IEC 60384-1:2021, 6.4 with the following details.

C_N:	≤ 1 µF	C_N:	>1 µF
Frequency:	10 kHz	Frequency:	1 kHz
Voltage:	1 V RMS. max.	Peak voltage:	≤ 3 % of rated voltage

When preconditioning is performed, initial measurements shall be carried out after preconditioning.

5.16.3 Test conditions

The capacitors shall be subjected to 10 000 cycles of charge and discharge at the rate of approximately one operation per second.

Each cycle shall consist of charging and discharging the capacitor. For AC capacitors, the test voltage shall be $\sqrt{2} \times U_\mathrm{R}$ and for DC capacitors the test voltage shall be U_R.

Each capacitor shall be individually charged by applying the test voltage through a resistor with the value

$$R = \frac{220 \times 10^{-6}}{C_\mathrm{N}} \ \Omega$$

or the value required to limit the charge current to 1 A (or to the higher current value given in the detail specification), whichever resistance value is the greater.

Each capacitor shall be individually discharged through a resistor of such a value that the maximum rate of change of voltage ($\mathrm{d}U/\mathrm{d}t$) shall be approximately 100 V/µs.

For RC units, if it is impossible to achieve a discharge rate of 100 V/µs, the RC unit shall be discharged through a short circuit.

The circuit is given in Annex C.

In Annex E (Pulse test circuits), alternative possibilities for a test circuit are given for information.

5.16.4 Final measurements and requirements

The capacitor shall be measured and shall meet the requirements of Table 14.

Table 14 – Charge and discharge – Requirements

Inspection or measurement	Inspection or measuring method	Requirements
Capacitance	5.3.2	The final capacitance value shall be within 10 % [a] of the value in Group 0 of Table 15 or Table K.1, as applicable
Tan δ for $C_\mathrm{N} \leq 1$ µF $f = 10$ kHz (if applicable)	5.16.2	The increase of tan δ over the value measured in 5.16.2 shall not exceed 80×10^{-4}
Tan δ for $C_\mathrm{N} > 1$ µF $f = 1$ kHz (if applicable)	5.16.2	The increase of tan δ over the value measured in 5.16.2 shall not exceed 50×10^{-4}
Resistance (if applicable)	5.3.4	$\lvert \Delta R / R \rvert \leq 10$ %
Insulation resistance	5.3.5	Greater than 50 % of the applicable limits of Table 5 or Table 6

[a] For ceramic capacitors, the capacitance difference shall not exceed 20 %.

5.17 Radiofrequency characteristics

The detail specification may prescribe measuring methods and requirements for one or more of the following radiofrequency characteristics:

- the main resonant frequency of the capacitor;
- insertion loss (the methods of CISPR 17 shall be used where possible);
- resistance at resonant frequency;
- impedance of the capacitor;
- inductance of the capacitor.

5.18 Passive flammability test

5.18.1 Testing according to IEC 60384-1

5.18.1.1 General

See IEC 60384-1:2021, 10.1 with the following details.

No test according to Group 0 and no preconditioning are required.

The test shall be carried out on 6 to 18 specimens, depending on the number of case sizes tested. The smallest, a medium (in the case of more than 4 case sizes in the range to be qualified), and the largest case size in the range to be qualified, shall be tested. For each case size, 3 specimens, each of the highest and lowest capacitance values of the range to be qualified, shall be tested.

The flame shall be applied for the period of time specified in the generic specification corresponding to the volume of the specimen and the category of flammability specified in the detail specification.

The preferred category is category B. If category C is used, it shall be agreed between the component supplier and the customer.

Exemption: for components smaller than 1 750 mm^3, passive flammability category C is permitted.

Passive flammability categories better than C may require flame retardant additives, which can be considered to cause environmental impact. These categories should be subject to discussion between manufacturers and customers to find a compromise between safety and environmental requirements.

For surface mount capacitors consisting of ceramic and metal, only the passive flammability test can be omitted.

5.18.1.2 Requirements

The burning time specified in the generic specification shall not be exceeded by any specimen. The tissue paper shall not ignite. No electrical measurements are required.

5.18.2 Alternative passive flammability test

5.18.2.1 General

In situations where the components do not have passive flammability category B, or where category C has not been agreed upon, and the volume of the capacitor is greater than 1 750 mm^3, or when the polymeric enclosure materials are not classified V-0 in accordance with IEC 60695-11-10, the following alternative test method can be used.

Three samples of the component are to be subject to three 15 s applications of a test flame, the period between the applications of the flame being 15 s. The component shall not continue to flame for more than 15 s after the first and second applications, and not more than 60 s after the third application.

5.18.2.2 Requirements for the test set-up

For the test, a supply of gas having a heating value of approximately 37,6 MJ/m^3 (1 000 Btu/ft^3) at normal pressure and a 9,5 mm (3/8 inch) diameter Tirril burner are to be used. The test flame is to be 19 mm (3/4 inch) high with the air ports of the burner closed.

5.18.2.3 Requirements for the conduction of the test

Each component is to be mounted in a position that is most conductive to the ignition of the component and that is permitted by the physical construction of the component. The tip of the test flame is to be applied at any location on the body of each component. No electrical measurements are required.

5.19 Active flammability test

5.19.1 Test condition

The active flammability test for Y1 capacitors is omitted because the current test set-ups can create excessive over-voltage on a Y1 capacitor.

The sample of 24 specimens shall contain equal numbers of specimen of the highest, the lowest and an intermediate capacitance value in the range to be qualified. Where there are only two capacitance values in the range, 12 of each value shall be tested; where only 1 capacitance value is involved, 24 capacitors of this value shall be tested.

The specimens shall be individually wrapped in at least 1, but not more than 2, complete layers of cheesecloth. The cheesecloth shall be untreated pure cotton cloth with a mass of 20 g/m^2 to 60 g/m^2 and having a count of between 22 × 27 and 45 × 34 that has been pre-conditioned under standard atmospheric conditions for testing for 24 h.

Each test capacitor shall be mounted by its leads. The free length of the leads should be at least 25 mm.

Using the test circuit of Figure 7 with the following details:

$U\sim$ = $U_R \pm 5$ %

U_i = 5 kV $^{+7}_{0}$ % for capacitors of Class Y2

= 4 kV $^{+7}_{0}$ % for capacitors of Class X1

= 2,5 kV $^{+7}_{0}$ % for capacitors of Class X2 and Y4

Each sample shall be subjected to 20 discharges from a tank capacitor, charged to a voltage that, when discharged, places U_i across the capacitor under test. The interval between successive discharges shall be $5\,^{+1}_{0}$ s. See Figure 8 for the intended wave form.

Throughout the test, the $U\sim$ shall be applied across the capacitor under test and shall be maintained for $120\,^{+10}_{0}$ s after the last discharge, unless a blown fuse causes an open circuit.

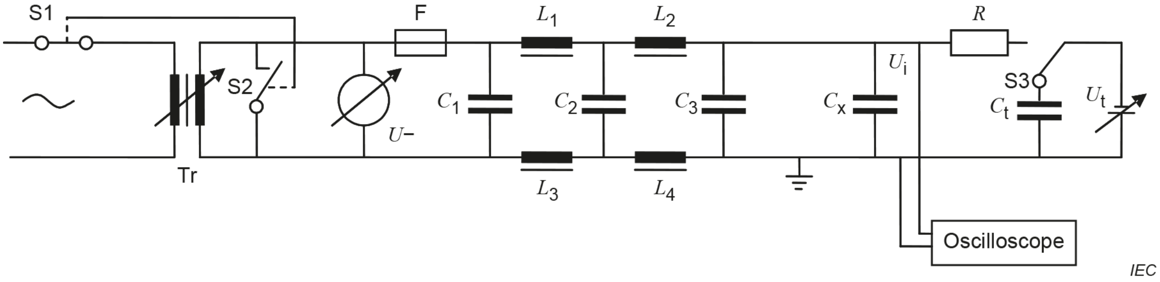


Figure 7 – Typical circuit for pulse loading of capacitors under AC voltage

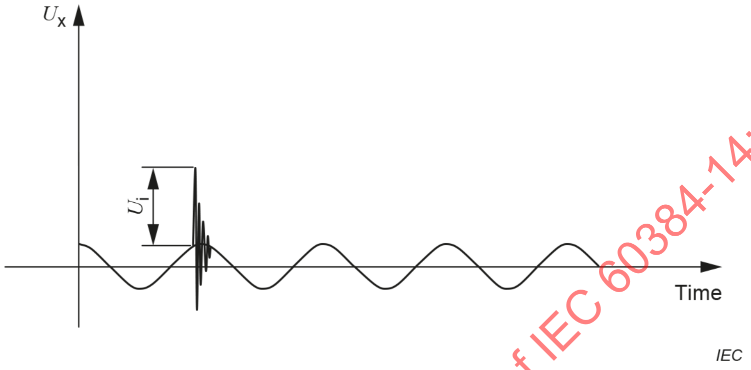


Figure 8 – Fundamental AC wave with randomly, not synchronized, superimposed high-voltage pulse

Tr = isolation transformer for blocking with secondary voltage of $U\sim$, and a sufficient capacity to supply 16 A to the test circuit at a voltage of ≥ 0,9 × $U\sim$;

C_1, C_2 = filter capacitor 1 µF ± 10 %;

L_1 .. L_4 = rod core choke 1,5 mH ± 20 %, 16 A;

C_3 = capacitor 0,033 µF ± 5 %;

R = 5 Ω ± 2 % for $C_x \geq 1$ µF;

= 10 Ω ± 2 % for 0,22 µF ≤ C_x < 1 µF;

= 40 Ω ± 2 % for 0,068 µF ≤ C_x < 0,22 µF;

= 100 Ω ± 2 % for C_x < 0,068 µF;

C_x = capacitor under test;

U_t = voltage to which the tank capacitor C_t is charged;

C_t = tank capacitor is 3 µF ± 5 % up to C_x = 1 µF, and ≥3 × C_x for C_x > 1 µF. The recommended value is 3 × C_x, but it is allowed to use a reasonably higher value in order to standardize the test equipment;

F = slow-blow fuse, rated 16 A.

NOTE C_1, C_2 and L_1 … L_4 comprise a mains protection filter; other configurations for these filters are permitted.

C_3 and C_t should have a suitable voltage compared to the required U_t during test.

5.19.2 Adjustment of U_i

The AC voltage shall be switched off by S_1 and the secondary winding of the transformer shall be short-circuited by S_2. A set-up capacitor of capacitance C_x with a tolerance of ± 5 % shall be connected in the C_x position. U_t shall then be adjusted so that the required peak voltage U_i appears across capacitor C_x, as demonstrated by the oscilloscope. The test shall then be conducted on the capacitors under test using this setting of U_t.

5.19.3 Requirements

The cheesecloth around the capacitor shall not burn with a flame. No electrical measurements are required.

5.20 Component solvent resistance (if applicable)

See IEC 60384-1:2021, 9.4 with the following details.

The detail specification shall specify whether tests are required using solvents additional to those specified in the generic specification.

The requirements shall be specified in the detail specification.

5.21 Solvent resistance of the marking

See IEC 60384-1:2021, 9.5 with the following details.

The detail specification shall specify whether tests are required using solvents additional to those specified in the generic specification.

The marking shall be legible.

6 Marking

6.1 General

See IEC 60384-1:2021, 4.3 with the following details.

6.2 Information for marking

The information given in the marking is normally selected from the following list. The relative importance of each item is indicated by its position in the list:

a) manufacturer's name or trademark;
b) manufacturer's type designation or the type designation given in the detail specification;
c) capacitor class and subclass;
d) recognized approval mark;
e) nominal capacitance(s) and nominal resistance;
f) rated voltage and nature of supply (alternating voltage may be indicated by the symbol ∼ (IEC 60417-5032:2002) and direct voltage by the symbol ⎓ (IEC 60417-5031:2002) or —— , also AC and DC respectively for alternating voltage and direct voltage can be used;
g) the method of connection, if necessary;
h) rated current of the conductor (in the case of a lead-through capacitor);
i) tolerance on nominal capacitance if different from ±20 %;

j) climatic category, followed by a letter indicating passive flammability category;

k) rated temperature;

l) year and month (or week) of manufacture;

m) reference to the detail specification.

6.3 Marking of capacitors

The capacitor shall be clearly marked with a), b) and c) and also d), e) and f) in 6.2, if these are not implied by b) in 6.2, and as many of the remaining items as are considered necessary by the manufacturer. The marking shall be sufficient to enable clear identification of the component.

NOTE For surface mount components, see Annex F.

It is recommended that a caution mark be printed on the printed circuit board where a safety component is mounted. The caution mark shall be ISO 7000-0434:2004. The mark is in the form of an upright equilateral triangle containing an exclamation mark.

This caution mark is referred to in IEC 62368-1:2018, Annex F (Clause F.5 and Table F.2). Any duplication of information in the marking on the capacitor should be avoided.

6.4 Marking of packaging

The package containing the capacitor(s) shall be clearly marked with all the information listed above. National approvals may be indicated by lettering as an alternative to the approval mark.

6.5 Additional marking

Any additional marking shall be applied in such a way that no confusion can arise.

7 Information to be given in a detail specification

7.1 General

Detail specifications shall be derived from the relevant blank detail specification.

Detail specifications shall not specify requirements inferior to those of the generic, sectional, or blank detail specification. When more severe requirements are included, they shall be listed in the relevant clause of the detail specification, and indicated in the test schedules, for example, by an asterisk.

The information in 7.2 to 7.4 shall be given in each detail specification and the values quoted should be selected from the appropriate clause of this sectional specification.

Requirements for safety approved AC capacitors to be used in DC applications are found in Annex H.

The information given in 7.2 may, for convenience, be presented in tabular form.

7.2 Outline drawing and dimensions

There shall be an illustration of the capacitor as an aid to easy recognition and for comparison of the capacitor with others. Dimensions and their associated tolerances, which affect interchangeability and mounting, shall be given in the detail specification. All dimensions should be stated in millimetres; however, when the original dimensions are given in inches, the converted metric dimensions in millimetres shall be added.

Normally, the numerical values shall be given for the length, width and height of the body and the wire spacing, or for cylindrical types, the body diameter and the length and diameter of the terminations. When necessary, for example when several capacitance values/voltage ranges are covered by a detail specification, their dimensions and their associated tolerances shall be placed in a table below the drawing.

When the configuration is other than that described above, the detail specification shall state such dimensional information as will adequately describe the capacitor. When the capacitor is not designed for use on printed boards, this shall be clearly stated in the detail specification.

7.3 Mounting

The detail specification shall specify the method of mounting to be applied for normal use and for the application of the vibration, bump, or shock tests. The capacitors shall be mounted by their normal means. The design of the capacitor may be such that special mounting fixtures are required for its use. In this case, the detail specification shall describe the mounting fixtures and they shall be used in the application of the vibration, bump, or shock tests.

If recommendations for mounting for "normal" use are made, they should be included in the detail specification under "Additional information (not for inspection purposes)". If recommendations are included, a warning can be given that the full vibration, bump and shock performance may not be available if mounting methods other than those specified in 1.1 of the detail specification are used.

7.4 Ratings and characteristics

7.4.1 General

The ratings and characteristics shall be in accordance with the relevant clauses of this specification, together with information in 7.4.2 to 7.4.4.

7.4.2 Nominal capacitance range

The preferred range of capacitance values should follow 4.2.1 of this document.

When products approved to the detail specification have different ranges, the following statement should be added: "The range of values available in each voltage range is given in the register of approvals, available for example on the website www.iecq.org".

7.4.3 Nominal resistance range (if applicable)

The preferred range of resistance values should follow 4.2.4 of this document.

7.4.4 Particular characteristics

Additional characteristics may be listed, when they are considered necessary to specify the component adequately for design and application purposes.

8 Assessment procedures

8.1 Primary stage of manufacture

For wound capacitors, the primary stage of manufacture is the winding of the capacitor element. For single-layer ceramic capacitors, it is the metallization of the dielectric to form the electrodes. For fixed multilayer ceramic capacitors, it is the first common firing of the dielectric-electrode assembly. For other types of capacitors, it shall be the same as that given in the sectional specification for the dielectric used.

8.2 Structurally similar components

Capacitors considered as being structurally similar are capacitors produced with essentially the same processes and materials, though they can be of different case sizes and capacitance values, but of the same class and rated voltage.

8.3 Certified records of released lots

The information required in IEC 60384-1:2016, Q.1.5, shall be made available when prescribed in the detail specification and when requested by a customer. After the endurance test, the parameters for which variable information is required are capacitance change, resistance change (for RC units), tan δ and insulation resistance.

8.4 Approval testing

8.4.1 Safety tests only qualification approval

Table 15 and Table 17 form a schedule limited to tests concerning safety only requirements. The schedule to be used for safety tests only approval will be because of fixed sample sizes as given in 8.4.3 and Table 15 of this document. Prior to the approval testing being carried out, it is necessary to submit to the certification body a declaration of design (see Annex D) registering essential data and basic design details of the capacitors for which approval is sought.

8.4.2 Qualification approval based on safety and performance testing

See Annex K.

8.4.3 Qualification approval based on the fixed sample size procedure

8.4.3.1 Sampling

Capacitors of each technology, rated voltage, class, and subclass shall be separately qualified. The total number of capacitors of each rated voltage in each group is given in Table 15 and Table 16 or Table K.1 and Table K.2. For multi-section capacitors containing sections of different classes and for lead-through capacitors, larger numbers are required as indicated.

The sample shall contain equal numbers of specimens of the highest and lowest capacitance values in the range to be qualified, except for the passive flammability test of 5.18 and the active flammability test of 5.19. For the passive flammability test, the rules of sampling in 5.18, footnote d to Table 15 and footnote h to Table 16 shall be followed. For the active flammability test, the rules of sampling in 5.19 shall be followed. For RC units, the sample of highest capacitance values and the sample of the lowest capacitance values shall contain each, as nearly as possible, an equal number of resistors of the highest and lowest resistance value in the range to be qualified. Where only one capacitance value is involved, the total number of capacitors as stated in Table 15 and Table 16, or Table K.1 and Table K.2 shall be tested.

Spare specimens are permitted as follows:

1) one per capacitance value which may be used to replace the permitted nonconforming item in Group 0;
2) the remainder of the spare specimens may be required, if it is necessary, to repeat any test according to the provisions of footnote a of either Table 15 or Table K.1.

The numbers given in Group 0 assume that all subgroups are applicable. If this is not so, the numbers may be reduced accordingly.

When additional groups are introduced into the qualification approval test schedule, the number of specimens required for Group 0 shall be increased by the same number as that required for the additional groups.

Table 15 and Table 16 or Table K.1 and Table K.2 give the number of specimens to be tested in each group or subgroup together with the permissible number of nonconforming items in each case.

Where a range of ceramic capacitors to be qualified consists of different temperature characteristics (or coefficients) or the range of capacitors employs significantly different materials, the samples for Groups 2, 3 and 7 shall contain the specified quantity of specimens for each temperature characteristics (or coefficients) or dielectric material group as specified below:

Group A: Materials with relative permittivity $\varepsilon_r < 500$

Group B: Materials with relative permittivity $500 \leq \varepsilon_r < 5\,000$

Group C: Materials with relative permittivity $\varepsilon_r \geq 5\,000$

8.4.3.2 Tests

One of the complete series of tests indicated in Table 15 and Table 17 or Table K.1 and Table K.3 is required for the approval of capacitors of a single rated voltage covered by one detail specification. The tests of each group shall be carried out in the order given.

For surface mount capacitors, the specific requirements of Annex F and Table F.1 shall be followed.

The whole sample shall be subjected to the tests of Group 0 and then subdivided for the other groups.

A specimen found to be a nonconforming item during the tests of Group 0 shall not be used for the other groups.

"One nonconforming item" is counted when a capacitor has not satisfied the whole or part of the tests of a group.

Approval is granted when the number of nonconforming is zero.

Fixed sample size test schedules for safety tests only are given in Table 15, Table 16, and Table 17, for safety and performance qualification approval in Table K.1, Table K.2 and Table K.3. Table 15, Table 16, or Table 17 include the details for the sampling and permissible nonconforming items for the different tests or groups of tests. Table 17 or Table K.3, together with the details of test contained in Clause 5, give a complete summary of test conditions and performance requirements, and indicate where, for test methods or conditions of test, a choice shall be made in the detail specification.

The conditions of test and performance requirements for the fixed sample size schedule should be identical to those prescribed in the detail specification for the quality conformance inspection.

Table 15 – Sampling plan – Tests concerning safety requirements only

Group	Test	Subclause of this document	Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass Per group
0	Visual examination	5.2	30 + 12[b]+	0
	Capacitance	5.3.2	6[c] +	
	Resistance	5.3.4	6 to18[d]	
	Voltage proof	5.3.1	+24	
	Insulation resistance	5.3.5		
	Tangent of loss angle (metallized film and paper capacitors only)	5.3.3		
	Spares		14 + 6[c]	
1A	Creepage distances and clearances	5.2.2		
	Robustness of terminations	5.4	6	0[a]
	Resistance to soldering heat	5.5		
	Solvent resistance of the marking	5.21		
2	Damp heat, steady state	5.13	12	0[a]
3	Impulse voltage	5.14		
	Endurance	5.15		
	Class X and RC units	5.15.4	12[b]	
	Class Y and RC units	5.15.5	12[b]	0[a]
	Lead-through[e]	5.15.6	6[c]	
6	Passive flammability	5.18	6 to 18[d]	0
7	Active flammability	5.19	24	0

Tests in Group 0 can be carried out in any practical order, except for ceramic capacitors whose capacitance value shall be measured first.

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] If multi-section capacitors consisting of X- and Y-capacitors are to be tested, 12 specimens shall be taken for the tests on the X-capacitors and 12 other specimens for the tests on the Y-capacitors.

[c] Additional capacitors if lead-through capacitors are tested.

[d] The smallest, a medium (in the case of more than four case sizes) and the largest case size shall be tested. Of each case size, three specimens of the maximum capacitance and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.

[e] Attention is drawn to the option of carrying out a combined voltage/current test, as described in 5.15.8.

Table 16 – Test schedule and sampling plan for lot-by-lot tests

Safety tests only			
Group	**Clause number and test referred to Clause 5 of this document**	**Inspection level IL**	**Acceptance number**
A0	5.3.2 Capacitance	100 %[b]	
	5.3.4 Resistance[a]		
	5.3.1 Voltage proof [d]		
A1	5.2 Visual examination	S-4	0
	Dimensions[c]		
	5.3.5 Insulation resistance (Test A)	I	0

Tests in Group A0 and Group A2 can be made in any practical order, except for ceramic capacitors whose capacitance value shall be measured first.

The sampling sizes corresponding to inspection levels should be selected from IEC 61193-2:2007, Table 1.

[a] If applicable.

[b] May be carried out as end-of-line testing.

[c] This test may be replaced by in-production testing if the manufacturer installs SPC on dimensional measurements or other mechanisms to avoid parts exceeding limits.

[d] The voltage proof test shall be combined with a suitable monitoring method to detect defects in insulation resistance.

Table 17 – Test schedule for safety tests only

Subclause number and test [a]	**Conditions of test [a]**	**n and c [b]**	**Performance requirements[a]**
Group 0	**Non-destructive**	See Table 15	
5.2 Visual examination	See 5.2.2		No visible damage Legible marking
5.3.2 Capacitance	See 5.3.2		Within specified tolerance
5.3.4 Resistance (if applicable)	See 5.3.4		Within specified tolerance
5.3.1 Voltage proof	See 5.3.1		No permanent break-down or flashover. No visible damage. The creepage distance and clearance specified in Table 3 shall be ensured. See detail specification
5.3.3 Tangent of loss angle (metallized film and paper capacitors only)	See 5.3.3		As in Table 5
5.3.5 Insulation resistance	See 5.3.5		

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements[a]
Group 1A	**Destructive**	See Table 15	
5.2.2 Creepage distances and clearances			As in 5.2.2
5.4 Robustness of terminations	See 5.4 Severity: see detail specification		No visible damage
5.5 Resistance to soldering heat (if applicable)	See 5.5.2 No pre-drying See detail specification for the Method		
5.21 Solvent resistance of the marking	Solvent: ... Solvent temperature: ... Method 1 Rubbing material: cotton wool Recovery: ...		Legible marking
5.5.3 Final inspection and measurements	Visual examination		No visible damage
	Capacitance		See Table 7
	Resistance (if applicable)		See Table 7
Group 2	**Destructive**	See Table 15	
5.13 Damp heat, steady state			
5.13.2 Initial measurements	Group 0 measurements to be used		
5.13.3 Test conditions	See 5.13.3		
5.13.4 Final inspection and measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 10 and Table 11
	Resistance (if applicable)		See Table 10 and Table 11
	Voltage proof		See Table 10 and Table 11
	Insulation resistance		See Table 10 and Table 11
	Tan δ (if applicable)		See Table 10 and Table 11

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements[a]
Group 3	**Destructive**	See Table 15	
5.14.2 Initial measurements	Group 0 measurements to be used		
5.14 Impulse voltage	See 5.14.3 Peak voltage, see Table 1 and Table 2		
5.14.4 Requirements	See 5.14.4		Minimum 3/24 full undisturbed pulses
5.15 Endurance	See 5.15.2 Duration: 1 000 h Voltage, current and temperature: see 5.15.4, 5.15.5, 5.15.6 and 5.15.7		No permanent breakdown or flashover
5.15.8 Final inspection and measurements	See 5.15.8 Visual examination		No visible damage Legible marking
	Capacitance		See Table 13
	Resistance (if applicable)		See Table 13
	Voltage proof		See Table 13
	Insulation resistance		See Table 13
	Tan δ (if applicable)		See Table 13
Group 6	**Destructive**	See Table 15	
5.18 Passive flammability	See 5.18.1.1		See 5.18.1.2
Group 7	**Destructive**	See Table 15	
5.19 Active flammability	See 5.19.2		See 5.19.3
Tests in Group 0 can be carried out in any practical order, except for ceramic capacitors the capacitance value shall be measured first.			

[a] Subclause numbers of test conditions and requirements refer to Clause 5.

[b] n = number of specimens, c = number of permissible nonconforming items.

[c] When, for a ceramic capacitor, a precise measurement of capacitance drift is required, preconditioning according to Annex G should be performed as advised by the manufacturer.

8.5 Quality conformance inspection

8.5.1 General

Before submission to the quality conformance inspection, an appropriate 100 % voltage proof test between terminations in accordance with Table 4 shall be carried out.

The details of this test shall be the prerogative of the manufacturer, but the time shall be not less than 1 s.

If the test is performed in a time period between 1 s and 2 s, the voltage of Table 4 shall be increased to values above curve B of Figure 9.

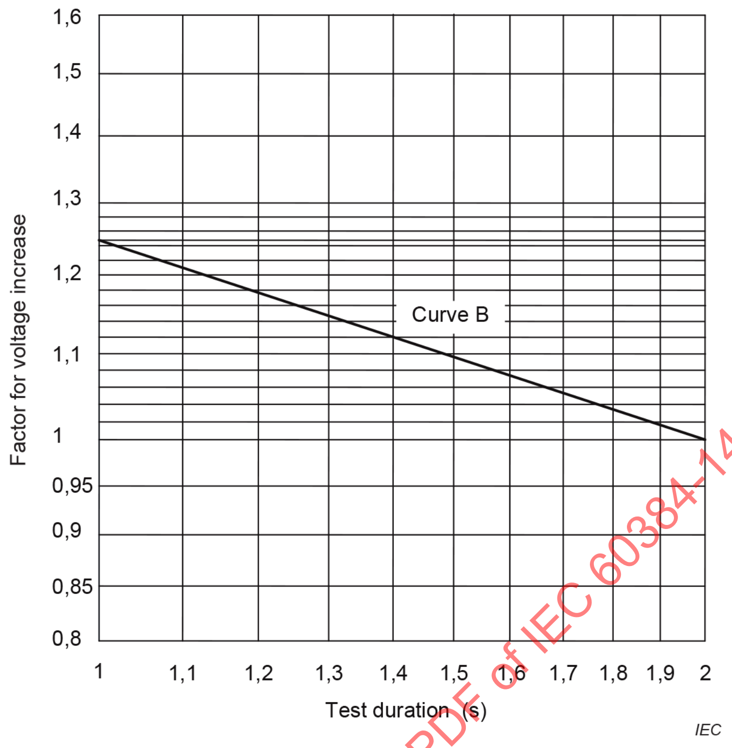


Figure 9 – Increased voltage for tests below 2 seconds

If a DC test voltage is used instead of AC for Y-capacitors, it shall be not less than 1,5 times the AC test voltage in Table 4 and further increased to values above curve B of Figure 9.

All nonconforming items shall be removed from the lot prior to lot-by-lot testing.

8.5.2 Formation of inspection lots

8.5.2.1 Group A inspection

These tests shall be carried out on a lot-by-lot basis in accordance with Table 15.

A manufacturer may aggregate the current production into inspection lots, subject to the following safeguards:

a) the inspection lot shall consist of structurally similar capacitors (see 8.2);

b) the sample tested shall be representative of the values and dimensions contained in the inspection lot:

   1) in relation to their number;

   2) with a minimum of five of any one value;

c) if there are less than five of any one value in the sample the basis for the drawing of samples shall be agreed between the manufacturer and the Certification Body.

For Group A tests, the inspection lot shall consist of components of the same rated voltage, class and subclass and shall be taken from one continuous production run.

No nonconforming items are permitted for Class Y-capacitors in the voltage proof test.

8.5.2.2 Group C inspection – Safety tests only approval

Re-qualification tests in accordance with Table 17 may be required by the certification body when a change of the declared design as given in Annex D is intended.

The certification body shall be informed about the intended change(s) and decide whether re-qualification tests shall be performed.

8.5.3 Test schedule for safety tests only approval

The schedule for the lot-by-lot tests or criteria for re-qualification is given in Table 16 and Annex D.

8.5.4 Delayed delivery

Re-inspection in the case of delayed delivery shall be carried out at intervals not exceeding three years. When according to the procedures of IEC 60384-1:2021, Q.1.7, re-inspection shall be made, voltage proof at the full relevant test voltage, capacitance, resistance (if applicable) and insulation resistance shall be checked as specified in Group A inspection and solderability shall be checked according to Group B inspection.

8.5.5 Assessment level

The assessment level DZ will be used. See Table 18.

Table 18 – Assessment level

	DZ		
Inspection subgroup [b]	**IL**	**Acceptance number**	
A1	S-4	0	
A2	I	0	
B1	S-3	0	
Inspection subgroup [b]	**DZ**		
	p	n	c [a]
C1A	6	6	0
C1B	6	12	0
C1	6	18	0
C2	6	12	0
C3	3		0
Class X		12	
Class Y		12	
Lead through		6	
C4	6	6	0
C5	12	4	0
C6	12	6 to 18	0
C7	12	24	0

The sampling sizes corresponding to inspection levels should be selected from IEC 61193-2:2007, Table 1.

IL = inspection level

p = periodicity in months

n = sample size

c = permissible number of nonconforming items

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] The content of the inspection subgroups is described in the relevant blank detail specification.

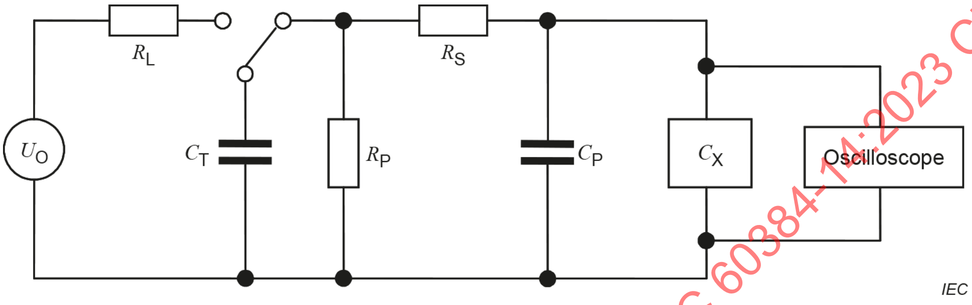
[c] The vibration, bump and shock tests in this subgroup are required to be carried out every 12 months only.

Annex A
(normative)

Circuit for the impulse voltage test

The 1,2/50 pulse shape in equipment standards, for example in IEC 62368-1:2018, Annex D, is defined under open circuit conditions, and a different shape is accepted in under load conditions.

The test prescribed in 5.14 shall be carried out using the circuit of Figure A.1 and the values given in Table A.1, as well as the values and tolerances given in Table A.2.



C_T = charging (or tank) capacitor

C_P = parallel capacitor

C_X = capacitor under test

R_L = loading resistor

R_S = series resistor, or charging resistor

R_P = parallel resistor, or discharging resistor

U_O = direct voltage source

Figure A.1 – Impulse voltage test circuit

Table A.1 – Values of C_X, C_T, R_P, R_S, C_p

Nominal value of C_X nF	**C_T ±10 %** µF	**R_P ±10 %** Ω	**R_S ±10 %** Ω	**C_p ±10 %** nF
$C_X \leq 3,9$	0,25	234	62	7,8
$3,9 < C_X \leq 12$	0,25	234	45	7,8
$12 < C_X \leq 18$	0,25	234	27	7,8
$18 < C_X \leq 27$	0,25	234	27	–
$27 < C_X \leq 39$	20	3	25	3,3
$39 < C_X \leq 56$	20	3	13	3,3
$56 < C_X \leq 82$	20	3	9	3,3
$82 < C_X \leq 120$	20	3	7	3,3
$120 < C_X \leq 180$	20	3	5	3,3
$C_X > 180$	20	3	3	3,3

Table A.2 describes the reference values and tolerances of C_X, t_r, and t_d to verify the test circuit setup.

Table A.2 – Values and tolerances of C_X, t_r, t_d

C_X ±2 %	t_r (0/+50) %	t_d (0/+50) %
μF	μs	μs
0,01	1,7	46
0,1	1,6	47

Annex B
(normative)

Circuit for the endurance test

The test prescribed in 5.15 shall be carried out with the following circuit (see Figure B.1).

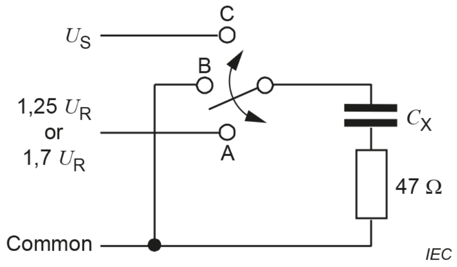


Figure B.1 – Endurance test circuit

C_X = capacitor under test.

U_S = 1,5 × U_R or 1 000 V RMS, whichever is higher

The part of the circuit for discharging the capacitor may be omitted if the switching between the two supplies is arranged to take place at the zero voltage point on the sinusoidal wave.

When the discharging circuit is used, the switching shall be arranged in the following sequence for each occasion when U_S is applied:

a) switch from position A to position B. Time for switching and remaining on position B is t_1;

b) switch from position B to position C. Time for switching and remaining on position C is t_2. Time on position C is 0,1 s;

c) switch from position C to position B. Time for switching and remaining on position B is t_3;

d) switch from position B to position A. Time for switching is t_4.

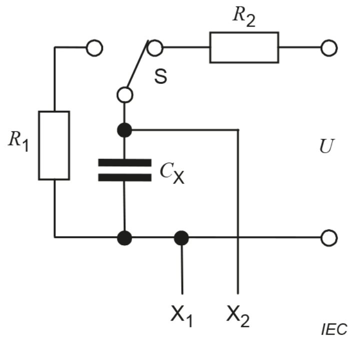
For any capacitor under test, the following condition shall be fulfilled:

$$t_1 + t_2 + t_3 + t_4 \leq 30 \text{ s}$$

Annex C
(normative)

Circuit for the charge and discharge test

The test prescribed in 5.16 shall be carried out with the following circuit (see Figure C.1).



C_X = capacitor under test

R_1 = current-limiting resistor (discharge)

R_2 = current-limiting resistor (charge)

S = switching device

U = test voltage

X_1, X_2 = terminals for oscilloscope connection to observe the maximum rate of change of voltage

Figure C.1 – Charge and discharge test circuit

Annex D
(normative)

Declaration of design
(confidential to the manufacturer and the certification body)

The purpose of this description is to register essential data and the basic design of the capacitors for which approval is sought. The completed form shall be submitted to the relevant certification body prior to any approval testing; its circulation to the other parties is left to the decision of the manufacturer.

Changes to the declared design are permitted only after notifying the certification body in writing. In this case, the certifying body will decide on necessary steps to be taken. As a maximum, a complete re-qualification can be required.

Registration number:

(To be allocated by the certifying body)

1 **Applicant**
2 **Manufacturer**
3 **Manufacturing site**
4 **Type designation**
5 **Class/subclass**
6 **Circuit diagram**
7 **Dielectric:**
7.1 Material
7.2 Thickness
7.3 Density (paper only)
7.4 Number of individual layers
8 **Electrode(s):**
8.1 Material
8.2 Method of production of electrode:
(For example, foil, evaporated onto film or paper)
9 **Capacitor element, arrangement of the individual layers**
10 **Impregnant** (if applicable)
11 **Encapsulation:**
11.1 Material(s) for cases, resins, etc. (as applicable)
11.2 Material of outer insulation (if applicable)
12 **Outline dimensions**

Location	Date	Name	Signature

Annex E
(informative)

Pulse test circuits

E.1 General

This annex describes alternative pulse testing circuits.

E.2 Test circuits

Figure E.1 shows the resistive pulse test circuit alternative and Figure E.2 the inductive test circuit alternative.

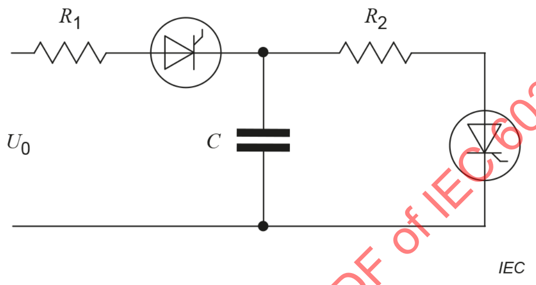


Figure E.1 – Resistive pulse test circuit

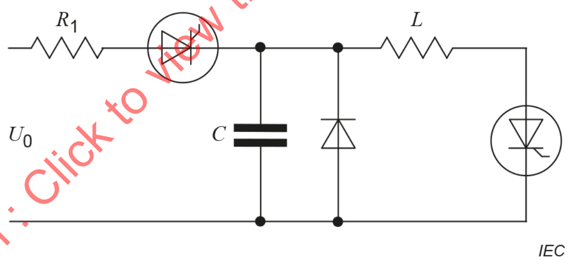


Figure E.2 – Inductive pulse test circuit

E.3 Charging of the capacitor

Figure E.3 shows the charging waveform for both test circuits, which is the same in both cases.

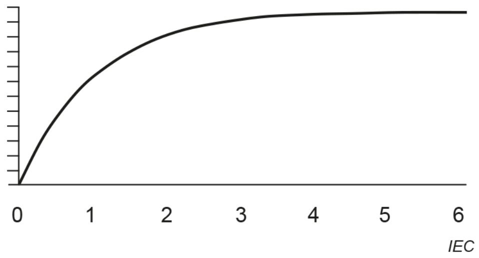


Figure E.3 – Charge waveform for both circuits

Timescale is in units of R_1C (R_1 is the charge resistor). The maximum value of dU/dt is derived as follows:

Q = CU, where Q is the charge on the capacitor and hence

$$I = C\frac{\mathrm{d}U}{\mathrm{d}t} \;\; \text{->} \;\; \left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{I_{\max}}{C}$$

E.4 Discharging of the capacitor

E.4.1 Discharging in resistive circuit

Figure E.4 shows the discharge waveform for the resistive circuit.

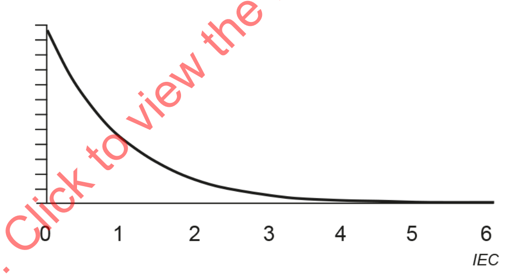


Figure E.4 – Discharge waveform for resistive circuit

Time scale is in units of R_2C (R_2 is the discharge resistor)

For the resistive circuit $I_{\max} = \frac{U_0}{R}$ ->

$$\left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{U_0}{RC}$$

which occurs at t = 0.

E.4.2 Discharging in inductive circuit

Figure E.5 shows the discharge waveform for the inductive circuit.

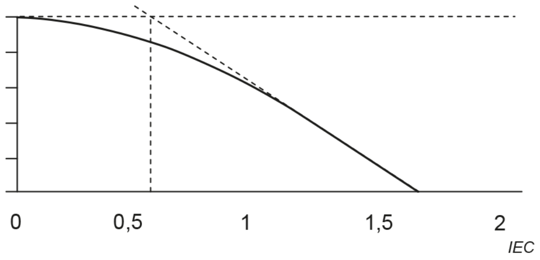


Figure E.5 – Discharge waveform for inductive circuit

Time scale is in units of $\sqrt{LC}$.

For the inductive circuit, if dissipation is neglected, the inductive energy with the initial capacitive energy is:

$$\tfrac{1}{2}LI_{\max}^2 = \tfrac{1}{2}CU_0^2 \text{ -> } I_{\max} = U_0\sqrt{\tfrac{C}{L}} \text{ -> } \left.\frac{\mathrm{d}U}{\mathrm{d}t}\right|_{\max} = \frac{U_0}{\sqrt{LC}}$$

which occurs at $t = \pi / 2\sqrt{LC}$.

Also since $U = L\frac{\mathrm{d}L}{\mathrm{d}t}$ > $\left.\frac{\mathrm{d}L}{\mathrm{d}t}\right|_{\max} = \frac{U_0}{L}$, this gives control of $\left.\frac{\mathrm{d}L}{\mathrm{d}t}\right|_{\max}$ and thus enables to avoid exceeding this rating of the switch in the discharge circuit.

In the resistive circuit, there is no such control, and the rating is liable to be exceeded when trying to achieve peak discharge.

Annex F
(normative)

Particular requirements for safety test of surface mount capacitors

F.1 General

Surface mount capacitors shall, in general, comply with all safety requirements of this document. Design, material, and mounting technology make it necessary to introduce new tests and adjust some existing methods and requirements.

The following paragraphs replace corresponding paragraphs in the main section of this document.

6.3 Marking of capacitors

The capacitors shall be clearly marked with a) and b) in Clause 6. The capacitors may also be marked with as many of the remaining items as possible taking account of the relative importance of each item. The marking shall be sufficient to enable a clear identification of the component.

7.3 Mounting

According to IEC 60384-1:2021, 5.5 for the safety test according to Table F.1, the manufacturer shall supply the test house with components unmounted or mounted on individual substrates, as indicated in Table F.1. The suitability of a proposed substrate shall be agreed between the manufacturer and the test laboratory. Details of the substrate, or substrates, used for the testing shall be included in the test report. An example of a substrate with conductive tracks is shown in Figure F.1.

F.2 Test and measurement procedures

The capacitor shall be tested in accordance with Table F.1 with the following deviations.

For an unencapsulated capacitor, test C in 5.3.1 and 5.3.5 shall be omitted.

5.3 Robustness of terminations is substituted with IEC 60384-1:2021, 7.7 and IEC 60384-1:2021, 7.8 and performed before the tests in Groups 2 and 3. Measurement of capacitance during the bending test may be omitted.

5.4 Resistance to soldering heat, if applicable, is performed as a separate test in accordance with IEC 60384-1:2021, 9.1.2.

5.5.3 Final inspection, measurements, and requirements

The capacitors shall be visually examined and measured and shall meet the requirements of Table 7.

Table F.1 – Test schedule and sampling plan for safety test of surface mount capacitors

Group	Clause number and test referring to Clause 5		Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass	
				Per group	Total
0	5.2	Visual examination [a]	30 + 12[d] + 6[f] + (6 to 18)[f] + 24	0	
	5.3.2	Capacitance			
	5.3.4	Resistance [c]			
	5.3.1	Voltage proof			
	5.3.5	Insulation resistance			
	5.3.3	Tangent of loss angle (metallized film and paper capacitors only)			
		Spares	14 + 6[e]		
1A	5.2.2	Creepage distances and clearances [a]	6	0[b]	
	5.5	Resistance to soldering heat [a, c]			
	5.21	Solvent resistance of the marking [a]			
	5.18	Passive flammability [a]	6 to 18[f]	0	
	Mounting according to 7.3		10 + 12[d] + 6[e] + 24		
2	7.7	of IEC 60384-1:2021, Shear test [g]	12	0[b]	
	7.8	of IEC 60384-1:2021, Substrate bending test			
	5.13	Damp heat, steady state			
3	7.7	of IEC 60384-1:2021, shear test [g]			0
	7.8	of IEC 60384-1:2021, substrate bending test			
	5.14	Impulse voltage			
	5.15	Endurance		0[b]	
	5.15.5	Class X and RC units	12[d]		
	5.15.6	Class Y and RC units	12[d]		
	5.15.7	Lead-through	6[e]		
4	5.19	Active flammability	24	0	

- Tests in Group 0 can be made in any practical order, except for ceramic capacitors whose capacitance value shall be measured first.
- Attention is drawn to the option of carrying out a combined voltage/current test as prescribed in 5.15.7.

[a] Samples for 5.2, 5.2.2, 5.5, 5.21 and 5.18 shall not be mounted on substrate during test.

[b] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted. The nonconforming items obtained in the first sample shall be counted for the total of nonconforming items permitted in the last column.

[c] If applicable.

[d] If multi-section capacitors consisting of X- and Y-capacitors are to be tested, 12 specimens shall be taken for the tests on the X-capacitors and 12 other specimens for the tests on the Y-capacitors.

[e] Additional capacitors if lead-through capacitors are tested.

[f] The smallest, a medium (in the case of more than four case sizes), and the largest case size shall be tested. Of each case size, 3 specimens of the maximum capacitance and 3 specimens of the minimum capacitance shall be tested, resulting in 6 specimens per case size.

[g] This test is to be performed alternatively to the substrate bending test, if the detail specification specifies mounting on rigid substrate (for example, alumina) only.

Dimensions in millimetres

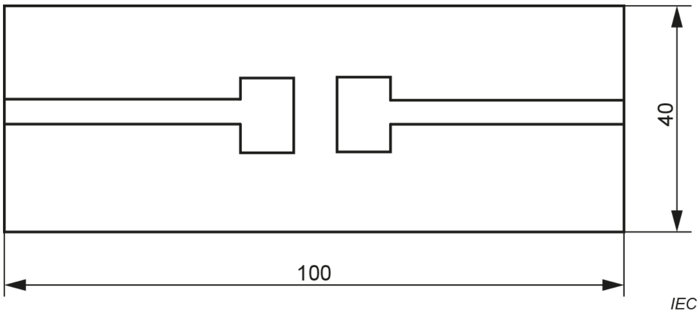


Figure F.1 – Example of test substrate for safety test according to Table F.1

Annex G
(informative)

Capacitance ageing of fixed capacitors of ceramic dielectric, Class 2

G.1 Overview

Most Class 2 dielectrics used for ceramic capacitors have ferroelectric properties and exhibit a Curie temperature.

Above this temperature, the dielectric has the highly symmetric cubic crystal structure whereas below the Curie temperature the crystal structure is less symmetrical. Although in single crystals this phase transition is very sharp, in practical ceramics it is often spread over a finite temperature range, but, in all cases, it is linked with a peak in the capacitance/temperature curve.

Under the influence of thermal vibration, the ions in the crystal lattice continue to move to positions of lower potential energy for a long time after the dielectric has cooled through the Curie temperature. This gives rise to the phenomenon of capacitance ageing, whereby the capacitor continuously decreases its capacitance.

However, if the capacitor is heated to a temperature above the Curie temperature, then de-ageing takes place, i.e. the capacitance lost through ageing is regained, and ageing recommences from the time when the capacitor re-cools.

G.2 Law of capacitance ageing

During the first hour after cooling through the Curie temperature, the loss of capacitance is not well defined, but after this time it follows a logarithmic law (see K.W. Plessner, Proc. Phys. Soc., vol. 69B, P1261, 1956) which can be expressed in terms of an ageing constant.

The ageing constant k is defined as the percentage loss of capacitance due to the ageing process of the dielectric which occurs during a "decade", i.e., a time in which the capacitor increases its age tenfold, for example, from 1 h to 10 h.

As the law of decrease of capacitance is logarithmic, the percentage loss of capacitance will be 2 × k between 1 h and 100 h age and 3 × k between 1 h and 1 000 h age. This may be expressed mathematically by the following equation:

$$C_\mathrm{t} = C_1 \left(1 - \frac{k}{100} \times \lg t\right)$$

where

C_t is the capacitance t h after the start of the ageing process;

C_1 is the capacitance 1 h after the start of the ageing process;

k is the ageing constant in percent per decade (as defined above);

t is the time in h from the start of the ageing process.

The ageing constant may be declared by the manufacturer for a particular ceramic dielectric, or it may be defined by de-ageing the capacitor and measuring the capacitance at two known times thereafter.

k is then given by the following equation:

$$k = \frac{100 \times (C_{t_1} - C_{t_2})}{C_{t_1} \times \lg t_2 - C_{t_2} \times \lg t_1}$$

If capacitance measurements are made three or more times, then it is possible to derive k from the slope of a graph where C_t is plotted against lg t.

It is also possible to plot lg C against lg t.

During measurements of ageing the capacitor should be maintained at a constant temperature so that capacitance variations due to the temperature characteristic do not mask those due to ageing.

G.3 Capacitance measurements and capacitance tolerance

Because of ageing, it is necessary to specify a reference age at which the capacitance shall be within the prescribed tolerance. This age is fixed at 1 000 h, since, for practical purposes, there is not much further loss of capacitance after this time.

In order to calculate the capacitance $C_{1\,000}$ after 1 000 h, the ageing constant shall be known or determined as in Clause G.2, when the following formula may be used:

$$C_{\mathrm{t}} = C_1 \left(1 - \frac{k}{100} \times \lg t\right)$$

For factory measurements, the loss of capacitance from the age at time of measurement to 1 000 h age will be known and can be offset by using asymmetric inspection tolerances.

For example, if it is known that the capacitance loss will be 5 %, then the capacitors may be inspected to limits of +25/−15 % instead of ±20 %.

Capacitance is normally declared at 20 °C, and it may be necessary to measure at this temperature or correct the results to this temperature. Errors can also arise from the hand temperature, and capacitors should therefore always be handled with plastic tweezers.

G.4 Special preconditioning

In many of the tests in this document, it is required to measure the capacitance change which results from a given conditioning (for example, climatic sequence). In order to avoid the interfering effect of ageing, the capacitor is specially preconditioned before these tests by maintaining it for 1 h at the upper category temperature followed by 24 h at standard atmospheric conditions for testing.

For those capacitors with a Curie temperature below the upper category temperature, this results in de-ageing and the conditioning is also arranged, if possible, to bring the capacitors to an age of 24 h, so that capacitance changes due to ageing are minimized.

If the Curie temperature of the dielectric is above the upper category temperature, then the special preconditioning will not completely de-age the capacitor, but it will nevertheless bring it into a state where its capacitance is not so dependent on its previous history. In order to de-age such capacitors completely, a temperature up to 160 °C may be required, and this temperature could be deleterious to the encapsulation. Therefore, in the few cases where complete de-ageing of such capacitors may be required, the detail specification shall be consulted for details and any necessary precautions.

Annex H
(normative)

Use of safety approved AC rated capacitors in DC applications

H.1 Overview

This annex gives additional requirements for AC EMI suppression capacitors for which safety approval is sought and which are connected to a DC supply with nominal voltage not exceeding 1 500 V DC.

If a safety approved capacitor fulfils the requirements of this annex, it is qualified at the rated DC voltage exceeding its approved rated AC voltage (RMS), without changing the capacitor class.

The manufacturer of the capacitor shall define the intended rated DC voltage, U_R DC, if it will exceed the certified rated AC voltage U_R AC.

H.2 Background

Safety capacitors approved to this document are AC capacitors which are essentially designed for applications where AC voltage is applied.

They have been allowed to be used in DC supplies having the same voltage as the rated AC voltage (RMS) of the capacitors. (See 3.1.1, Note 1 to entry).

The class of the capacitors, such as X1 and Y1, is defined according to their peak impulse withstanding voltage and the type of insulation bridged.

A capacitor used for AC voltage application is subjected to the voltage waveform with peak voltage equal to RMS voltage times square root of two, which is alternating polarity in a wave cycle, so that safety approved capacitors theoretically can withstand at least a DC voltage equivalent to their rated AC voltage times square root of two.

NOTE Many manufacturers are specifying that their AC capacitors can withstand clearly higher DC voltages than rated AC voltage times the square root of two.

H.3 Additional requirement for use of X- and Y-capacitors in DC applications

A capacitor, which is specified for rated DC voltage exceeding the rated AC voltage (RMS), shall fulfil the requirements specified in Table H.1 in addition to the tests listed in Table 13.

Table H.1 – Additional test conditions

Type	Maximum U_R DC	Test voltage DC (Test A) (according 5.3.1)	Endurance test (DC)	Damp heat, steady state test
X1	1 500 V	2,15 × U_R DC	In accordance with 5.15 using rated DC voltage instead of U_R, without voltage increased to U_S.	In accordance with 5.13, but with rated DC voltage applied to a sample of 6 pcs See Table 12.
X2	1 500 V			
Y1	1 500 V	4 × U_R DC [a]		
Y2	1 500 V	2,15 × U_R DC [a]		
Y4	450 V	2,15 × U_R DC [a]		

[a] If an AC test voltage is used instead of a DC voltage for Y-capacitors, it shall be not less than 0,666 × DC test voltage in Table H.1.

NOTE As an example, a typical X2 capacitor on the market, has rated AC voltage 300 V and rated DC voltage, U_R DC, 630 V. This means that the test voltage DC (Test A) is 2,15 × 630 V = 1 354,5 V.

H.4 Creepage and clearance distances

When a capacitor approved by this annex is used for a specific application, it shall be confirmed that creepage and clearance distances of the capacitor meet the requirements of the related standards for the application.

NOTE For examples of the specific standards and the requirements mentioned above, see IEC 60939-3:2015, Table 6 and Table 7.

Annex I
(normative)

Humidity robustness grades for applications, where high stability under high humidity operating conditions is required

I.1 Overview

In addition to the description of preferred climatic categories in 4.1 and test damp heat, steady state in 5.13, this annex describes specific humidity robustness grades and requirements for applications, where high stability under high humidity operating conditions is required.

I.2 Humidity robustness grades

I.2.1 General

For high humidity applications the Grade (I) robustness under humidity, Grade (II) robustness under high humidity and Grade (III) high robustness under high humidity are defined.

I.2.2 Grade (I) robustness under humidity

To verify Grade (I), either test condition A or B shall be selected by the manufacturer

Test condition A: Test damp heat, steady state; 40 °C ± 2 °C / (93 ± 3) % RH duration 21 days, rated voltage applied.

Test condition B: Test damp heat, steady state; 85 °C / 85 % RH duration 7 days (= 168 h), rated voltage applied.

NOTE Test condition B is a substitutional accelerated test for test condition A.

I.2.3 Grade (II) robustness under high humidity

To verify Grade (II), either test condition A or B shall be selected by the manufacturer

Test condition A: Test damp heat, steady state; 40 °C ± 2 °C / (93 ± 3) % RH duration 56 days, rated voltage applied.

Test condition B: Test damp heat, steady state; 85 °C / 85 % RH duration 500 h, rated voltage applied.

NOTE Test condition B is a substitutional accelerated test for test condition A.

I.2.4 Grade (III) high robustness under high humidity

To verify Grade (III), either test condition A or B shall be selected by the manufacturer.

Test condition A: Test damp heat, steady state; 60 °C ± 2 °C / (93 ± 3) % RH duration 56 days, rated voltage applied.

Test condition B: Test damp heat, steady state; 85 °C / 85 % RH duration 1 000 h, rated voltage applied.

NOTE Test condition B is a substitutional accelerated test for test condition A.

I.3 Test description

If the capacitors are specified for AC applications, one sample of ten pieces shall be tested with the rated AC voltage. If the capacitors are specified also for DC applications, and the rated DC voltage is exceeding the rated AC voltage (RMS), one additional sample of six pieces shall be tested with rated DC voltage. See Table 12. For requirements, see Table I.1.

Table I.1 – Requirements

Measurement	Measuring method	Requirements
Visual examination	5.2	No visible damage. In visual inspection after the test, the coating of the capacitor shall not have any cracks exposing internal live parts or in defined insulated areas (the creepage distance and clearance specified in Table 3 shall be ensured). The marking shall be legible
Capacitance	5.3.2	Metalized capacitors: $\lvert \Delta C \rvert$ ≤10 % Ceramic capacitors: $\lvert \Delta C \rvert$ ≤15 %
Tangent of loss angle (metallized capacitors only)	5.3.3	The increase of tan δ over the value measured in Group 0 shall not exceed 0,024 for $C_N \leq 1$ μF [a] 0,015 for $C_N > 1$ μF [a]
Resistance (if applicable)	5.3.4	$\lvert \Delta R/R \rvert \leq 5\ \%$
Voltage proof	5.3.1	Test voltage as in Table 4
Insulation resistance	5.3.5	> 50 % of the applicable limits of Table 5 or Table 6, or minimum 200 MΩ, whichever is higher

The change of capacitance value depends on technology, and, as for example in case of ceramic capacitors, can be reversible. Thus, the requirements are different.

[a] For certain applications, smaller values for the increase of tan δ may be required.

I.4 Indication of humidity robustness grades

In addition to the climatic category, information on the humidity robustness grade and the test method used for verification shall be indicated IA, IB, IIA, IIB, IIIA, or IIIB in the information provided by the manufacturer. Marking on the capacitor is not required.

Annex J
(normative)

Description of creepage/clearance distance measurement for cased and conformal coated capacitors

J.1 Measurement of creepage distances and clearance – general

J.1.1 General

Capacitors complying with this document are permitted to bridge certain levels of insulation. They are produced in various styles and shapes, using different encapsulation methods. All this can affect how the creepage distance and clearance is defined and measured. This annex gives an overview of different capacitor styles and how the creepage and clearance distances are determined in each case. In addition, it provides information about precautions in handling, in order not to cause damage to external insulation and coating of terminal pins.

For other capacitor styles than cased or conformal coated, the manufacturer shall define the clearance and creepage distances.

J.1.2 Capacitor styles

Figure J.1 and Figure J.2 show examples of cased and conformal coated capacitors.

Figure J.1 – Example of a cased capacitor

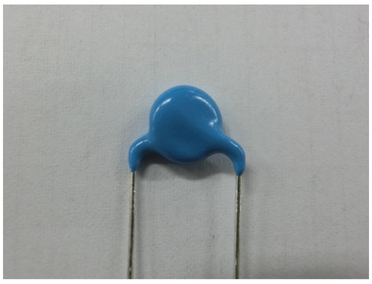


Figure J.2 – Example of a conformal coated capacitor

J.1.3 Capacitor body and terminal insulation

The case, or the coating comprising the case, shall fulfil the requirements of this document, which is ensured by design and by tests of the capacitor body's insulation. In the case of conformal coated capacitors, the design shall provide the minimum thickness of coating material. See Figure J.3, white part.

EXAMPLE A subclass Y1 capacitor is permitted to bridge double or reinforced insulation. The capacitor case or coating serves as double or reinforced insulation to other circuit parts, such as a transformer core or other conductive parts.

The coating on terminals (Figure J.3, grey area) is insulating the metallic leads and is defined as functional insulation (solid insulation material). Because its thickness and breakdown strength are not specified, it cannot be considered as a basic insulation.

It is important to note the different classification of a functional insulation depending upon the context it is used. It can be "conductive" as well as "insulation":

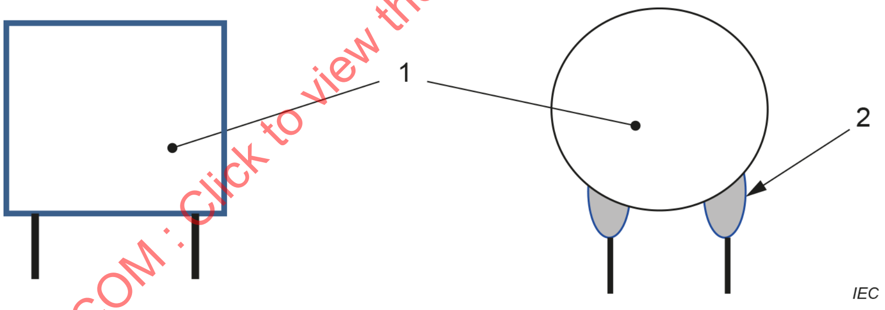
- For creepage distance, the relevant property is that it is a solid insulating material (non-conductive), independent from its thickness and breakdown strength.

  NOTE 1 Creepage distance is the shortest distance along the surface of a solid insulating material between two conductive parts(see IEC 60050-151, 151-15-50 and IEC 60050-581, 581-21-23).

- For clearance, the relevant property is the breakdown strength. The breakdown strength of a functional insulation is not specified, and when not tested, it shall be classified as conductive. In consequence, that means:
  - i) for clearance between the terminals, the breakdown strength of the insulation is tested by the voltage proof test (5.3.1, Test A), thus it fulfils the same requirements as the capacitor body's insulation;
  - ii) for clearance from a terminal to outside the capacitor, the breakdown strength of the insulation is not tested, thus the coating of the leads shall be classified as conductive to determine the clearance.

  NOTE 2 Clearance is the shortest distance in air between two conductive parts (see IEC 60050-581, 581-27-76).

Further details are given in Clause J.2.



Key:

1 Capacitor body insulation (case or conformal coating) – insulation is specified and tested

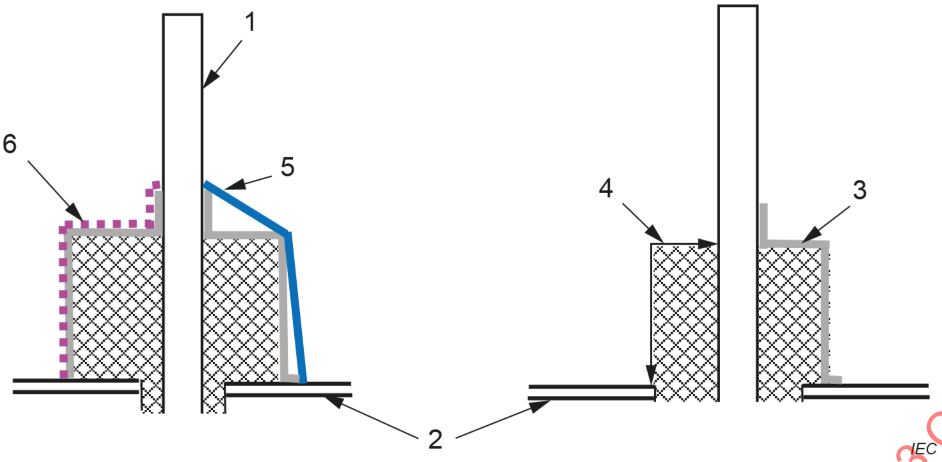
2 Coating on terminal – insulation is not specified, but tested between the terminals

Figure J.3 – Cased and conformal coated types

J.1.4 Measurement principle

Coatings may be used over external terminations of components to increase effective clearances and creepage distances (see Figure J.4). The mechanical arrangement and rigidity of the terminations shall be adequate to ensure that, during normal handling, assembly into equipment and subsequent use, the terminations will not be subject to deformation that would crack the coating or reduce the separation distances between conductive parts below the values in Table 3.

For measurement of creepage distance and clearance, the principles shown in Figure J.4 shall be applied.



Key

1	Terminal
2	Metal
3	Coating
4	Separation distance before coating
5	Clearance ▬
6	Creepage distance ▪▪▪▪▪▪

Figure J.4 – Description

In visual inspection, the coating of the capacitor including the coated part of terminals shall not have any cracks or defects exposing internal live parts or in defined insulated or coated areas (the creepage distance and clearance specified in Table 3 shall be ensured).

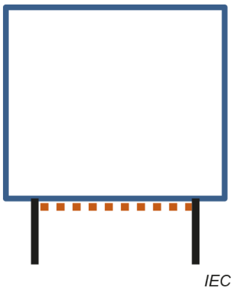
J.2 Measurement

J.2.1 Creepage distance between terminals

J.2.1.1 Cased style

The coating of terminals at the bottom side of cased capacitors normally is not specified. In that case, the creepage distance is set equal to the clearance, although following the bottom surface of the capacitor it can be a longer distance. See Figure J.5.

If the insulation of terminals at the bottom side of the capacitor is specified, the creepage distance shall be determined according to the requirements of the relevant safety standard.



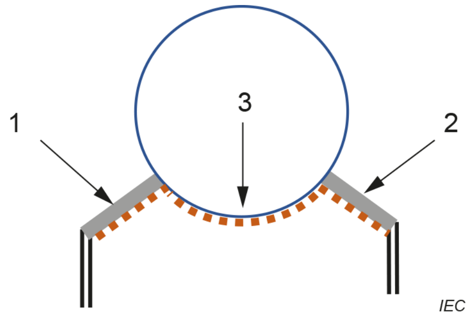
Key

▪▪▪▪▪ Creepage distance

Figure J.5 – Creepage distance – cased style

J.2.1.2 Conformal coated style

Creepage distance is the shortest distance along the surface of a solid insulating material between two conductive parts. It starts and ends at the end of conductive part of the leads. See Figure J.6.



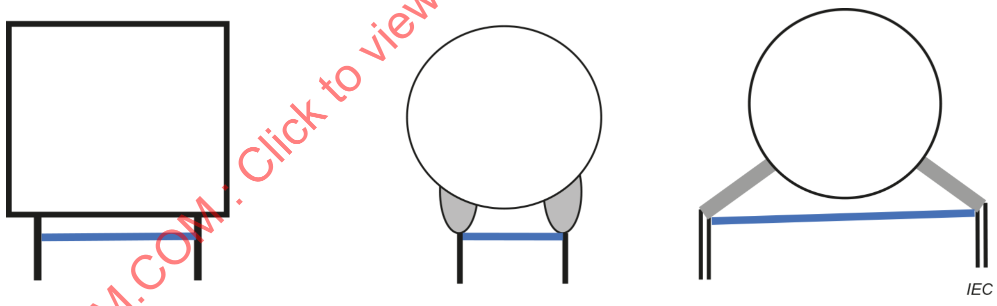
Key

1, 2	Grey area – coating on lead wires (solid insulation, not conductive)
3	Separation distance before coating (arc length)
▪▪▪▪▪	Creepage distance

Figure J.6 – Creepage distance – conformal coated style

J.2.2 Clearance between terminals

The clearance is the distance in air between the uncoated terminals. As the breakdown strength of the lead wire coating is tested by the voltage proof test (5.3.1, Test A), it fulfils the requirements to the capacitor body insulation between the terminals. See J.1.3 for additional explanation. Figure J.7 illustrates the clearance for different component constructions.



Key

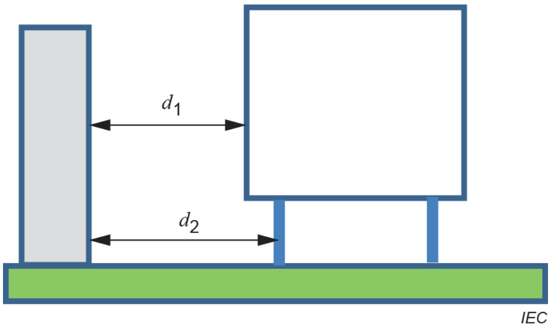
▬	Clearance

Figure J.7 – Clearance between terminals

J.2.3 Clearance in mounted stage

J.2.3.1 Cased style

For cased style capacitors, the definition of clearances in mounted stage is shown in Figure J.8. For requirements, see J.2.3.3.



Key:

d_1	Minimum distance between capacitor body and conductive parts
d_2	Minimum distance between capacitor terminals and conductive parts

Figure J.8 – Clearance in mounted stage – cased style

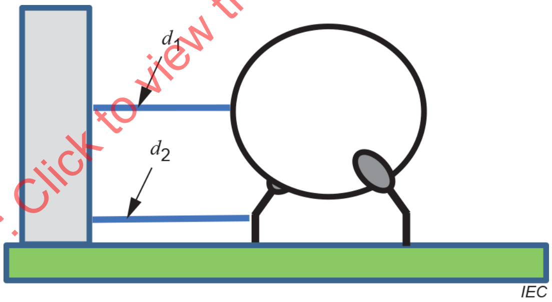
J.2.3.2 Conformal coated style

If the insulation of leads (between lead wire and the outside of coating) is not specified and checked to comply with the requirements, it shall not be considered as double/reinforced or basic insulation. Additional insulation to other conductive parts is needed if the distance is less than the clearance required by the relevant safety standard.

To determine the clearance, two cases shall be distinguished:

1) Capacitor body larger than lead pitch – Figure J.9

2) Capacitor body smaller than lead pitch – Figure J.10



Key

d_1	Clearance between body and a conductive part
d_2	Clearance between terminal and a conductive part

Figure J.9 – Clearance – capacitor body larger than lead pitch

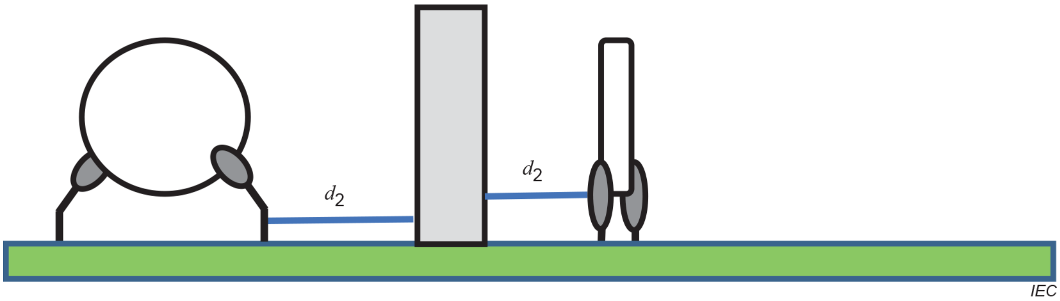


Figure J.10 – Clearance – capacitor body smaller than lead pitch

J.2.3.3 Requirements

The minimum distance d_1 may become "0" if the capacitor body coating complies to the required insulation level.

The minimum distance d_2 shall fulfil the requirements to clearances as given in the relevant safety standard.

Additional insulation (e.g., sleeve) shall be added if double or reinforced insulation is required and the minimum distance cannot be kept.

J.2.4 Conductors between terminals

Uncoated conductors or other conductive parts positioned underneath the capacitors are allowed, provided the design complies with the minimum creepage distance and clearance requirements. Otherwise, protective coating of the conductive parts is required, which complies with the relevant requirements to additional protective insulation.

A conductor between the terminals of a capacitor bridging double or reinforced insulation shall be coated with a suitable coating material complying with the requirements to double or reinforced insulation. For further information see IEC 60664-3.

J.3 Precautions in handling

Housing of conformal coated capacitors shall not be user accessible or exposed to undue mechanical stress, which could degrade the insulating properties of the housing material.

The coated part of lead wires shall be protected against bending (e.g., by clamping using a suitable tool) if the lead wires are formed before or during assembly to a board (e.g., kinking).

Annex K
(normative)

Safety and performance tests qualification approval

K.1 Overview

It is possible to qualify the products to cover wider range of parameters than the safety related ones. This annex describes the sampling plan, test schedule, sampling plan for lot-by-lot test and periodical testing for this wider qualification.

K.2 Qualification approval

Table K.1, Table K.2 and Table K.3 shall be used when qualification approval is sought.

The procedures for qualification approval testing are given in the generic specification, IEC 60384-1:2021, Q.2, in which Q.2.4 refers to lot-by-lot and periodic inspections. The schedules to be used for qualification approval testing on the basis of lot-by-lot and periodic inspections are given in 8.5 and Table K.4 of this document. The schedule to be used for qualification approval testing based on fixed sample sizes in accordance with IEC 60384-1:2021, Q.2.4, is given in 8.4.3, Table K.1 and Table K.2 of this document. For the two procedures, the sample sizes and the number of permissible nonconforming items shall be of comparable order. The test conditions and requirements shall be the same. Qualification approval according to the fixed sample sizes of Table K.1 and Table K.2 is preferred.

Table K.1 – Sampling plan – Safety and performance tests qualification approval – Assessment level DZ

Group	Test	Subclause of this document	Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass
0	Visual examination	5.2	52 + 12[d] +	0[a]
	Dimensions (gauging)	5.2	6[e] +	
	Capacitance	5.3.2	6 to 18[h]	
	Resistance	5.3.4	+24	
	Tangent of loss angle[g]	5.3.3		
	Voltage proof	5.3.1		
	Insulation resistance	5.3.5		
	Spares		20 + 6[f]	
1A	Dimensions (detail)	5.2	6	0[a]
	Robustness of terminations	5.4		
	Resistance to soldering heat	5.5		
	Component solvent resistance	5.20		
1B	Solderability	5.6	12	0[a]
	Solvent resistance of the marking	5.21		
	Rapid change of temperature	5.7		
	Vibration	5.8		

Group	Test	Subclause of this document	Number of specimens tested per rated voltage and subclass	Permitted number of nonconforming items per rated voltage and subclass
	Bump or shock[f]	5.9 or 5.10		
1	Container sealing [c]	5.11	18	0
	Climatic sequence	5.12		
2	Damp heat, steady state	5.13	12	0[a]
3	Impulse voltage	5.14		0[a]
	Endurance	5.15		
	Class X and RC units	5.15.5	12[d]	
	Class Y and RC units	5.15.6	12[d]	
	Lead-through[i]	5.15.7	6[e]	
4	Charge and discharge[b]	5.16	6	0[a]
5	Radiofrequency characteristics	5.17	4	0[a]
6	Passive flammability	5.18	6 to 18[h]	0
7	Active flammability	5.19	24	0

Tests in Group 0 can be made in any practical order, except for ceramic capacitors the capacitance value shall be measured first.

[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.

[b] If applicable.

[c] If required in the detail specification.

[d] If multi-section capacitors consisting of X- and Y-capacitors are to be tested, 12 specimens shall be taken for the tests on the X-capacitors and 12 other specimens for the tests on the Y-capacitors.

[e] Additional capacitors if lead-through capacitors are tested.

[f] Whichever is stated in the detail specification.

[g] Not required for RC units, or for capacitors other than those of metallized film or metallized paper construction.

[h] The smallest, a medium (in the case of more than four case sizes) and the largest case size shall be tested. Of each case size, three specimens of the maximum capacitance and three specimens of the minimum capacitance shall be tested, resulting in six specimens per case size.

[i] Attention is drawn to the option of carrying out a combined voltage/current test as stated in 5.15.7.

Table K.2 – Test schedule and sampling plan for lot-by-lot tests

Safety and performance tests qualification approval – Assessment level DZ			
Group	**Clause number and test referred to Clause 5 of this document**	**Inspection level IL**	**Acceptance number [b]**
A1	5.2 Visual examination	S-4	0
	5.2 Dimensions (gauging)		
A2	5.3.2 Capacitance	I	0
	5.3.4 Resistance [a]		
	5.3.3 Tangent of loss angle (metallized film and paper capacitors only)		
	5.3.1 Voltage proof (Test A)		
	5.3.5 Insulation resistance (Test A)		
B1	5.6 Solderability [a]	S-3	0

[a] If applicable.

[b] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample, and then no further nonconforming items are permitted.

Table K.3 – Test schedule for safety and performance tests qualification approval Assessment level DZ

Subclause number and test [a]	**Conditions of test [a]**	***n* and *c* [b]**	**Performance requirements [a]**
Group 0	**Non-destructive**	See Table K.1	
5.2 Visual examination			No visible damage Legible marking and as specified in the detail specification
5.2 Dimensions (gauging)			See detail specification
5.2.2 Creepage distances and clearances			See detail specification and Table 3
5.3.2 Capacitance			Within specified tolerance
5.3.4 Resistance (if applicable)			Within specified tolerance
5.3.3 Tangent of loss angle (metallized film and paper capacitors only)	Frequency: …		See detail specification
5.3.1 Voltage proof	Method: …		No permanent break-down or flashover
5.3.5 Insulation resistance	Method: …		See Table 6

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements [a]
Group 1A	**Destructive**	See Table K.1	
5.2 Dimensions (detail)			See detail specification and Table 13
5.4 Robustness of terminations	Severity: see detail specification		No visible damage
5.5 Resistance to soldering heat (if applicable)	No pre-drying See detail specification for the Method 1		
5.20 Component solvent resistance (if applicable)	Solvent: … Solvent temperature: … Method 2		See detail specification
	Recovery: …		
5.5.3 Final measurements	Visual examination		No visible damage
	Capacitance		See Table 7
	Resistance (if applicable)		See Table 7
Group 1B	**Destructive**	See Table K.1	
5.6 Solderability (if applicable)	Without ageing For method see detail specification		Good tinning as evidenced by free flowing of the solder with wetting of the terminations or solder shall flow within 3 s, as applicable.
5.21 Solvent resistance of the marking	Solvent: … Solvent temperature: … Method 1 Rubbing material: cotton wool		Legible marking
	Recovery: …		
5.7 Rapid change of temperature	T_A = Lower category temperature T_B = Upper category temperature		
	Five cycles Duration t_1 = 30 min		
5.7.2 Final inspection	Visual examination		No visible damage
5.8 Vibration	For mounting method and severity: see detail specification		
5.7.2 Final inspection	Visual examination		No visible damage
5.9 Bump (repetitive shock) or 5.10 Shock	For mounting method and severity: see detail specification		
5.9.3 Final measurements or 5.10.3	Visual examination		No visible damage
	Capacitance		See 5.9.3 or 5.10.3
	Resistance (if applicable)		See Table 9

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements [a]
Group 1	**Destructive**	See Table K.1	
5.11 Container sealing (if applicable)	Test Qc or Test Qd of IEC 60068-2-17 as prescribed in the detail specification		No evidence of leakage
5.12 Climatic sequence			
5.12.2 Initial measurements	Measurements made in 5.5.3, 5.9.3 or 5.10.3 as appropriate		
5.12.3 Dry heat	Temperature: upper category temperature Duration: 16 h		
5.12.4 Damp heat, cyclic, test Db, first cycle			
5.12.5 Cold	Temperature: lower category temperature Duration: 2 h		
5.12.6 Damp heat, cyclic, test Db, remaining cycles			
5.12.7 Final measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 9
	Resistance (if applicable)		See Table 9
	Tan δ (if applicable)		See Table 9
	Voltage proof		See Table 9
	Insulation resistance		See Table 9
Group 2	**Destructive**	See Table K.1	
5.13 Damp heat, steady state			
5.13.2 Initial measurements	Group 0 measurements to be used		
5.13.3 Test conditions	Ceramic capacitors: half of the sample with U_R applied; the other half with no voltage applied Other capacitors: no voltage applied		
5.13.4 Final measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 10 and Table 11
	Resistance (if applicable)		-"-
	Tan δ (if applicable)		-"-
	Voltage proof		-"-
	Insulation resistance		-"-

Subclause number and test [a]	Conditions of test [a]	n and c [b]	Performance requirements [a]
Group 3	**Destructive**	See Table K.1	
5.14.2 Initial measurements	Group 0 measurements to be used		
5.14 Impulse voltage	3 pulses, full wave Number of impulses: 24 max. Peak voltage: ... V, see Table 1 and Table 2		See 5.14.3 and 5.14.4
5.15 Endurance	Duration: 1 000 h Voltage, current and temperature: see 5.15.4, 5.15.5, 5.15.6 and 5.15.7		
5.15.8 Final measurements	Visual examination		No visible damage Legible marking
	Capacitance		See Table 12
	Resistance (if applicable)		See Table 12
	Tan δ (if applicable)		See Table 12
	Voltage proof		See Table 12
	Insulation resistance		See Table 12
Group 4	**Destructive**	See Table K.1	
5.16 Charge and discharge	Only for metallized and ceramic capacitors and RC units using such capacitors		
5.16.2 Initial measurements	Group 0 measurements may be used, provided the measuring conditions are the same as required for this test; in addition, except for RC units, tan δ shall be measured at: 10 kHz for $C_N \leq 1$ µF 1 kHz for $C_N > 1$ µF		
5.16.4 Final measurements	Capacitance		See Table 13
	tan δ at same frequency as initial measurement (not for RC units)		See Table 13
	Resistance (if applicable)		See Table 13
	Insulation resistance		See Table 13
Group 5	**Non-destructive**	See Table K.1	See detail specification
5.17 Radiofrequency characteristics	If required in the detail specification; see detail specification for measuring method		
Group 6	**Destructive**	See Table K.1	See 5.18.1
5.18 Passive flammability			
Group 7	**Destructive**	See Table K.1	See 5.19.3
5.19 Active flammability			
Tests in Group 0 can be made in any practical order, except for ceramic capacitors the capacitance value shall be measured first			

[a] Subclause numbers of test conditions and requirements refer to Clause 5.

[b] n = number of specimens, c = number of permissible nonconforming items.

[c] When, for a ceramic capacitor, a precise measurement of capacitance drift is required, preconditioning in accordance with Annex G should be performed as advised by the manufacturer.

K.3 Quality conformance inspection

K.3.1 General

In addition to 8.5, the content of K.3.2, K.3.3 and K.3.4 shall be followed:

K.3.2 Groups A and B inspection

These tests shall be carried out on a lot-by-lot basis according to Table K.4.

For Group B tests, the inspection lot shall consist of components produced with similar processes and materials, according to the test concerned.

K.3.3 Group C inspection

To maintain the qualification, the qualification approval tests shall be carried out on a periodic basis.

The samples to be submitted to the periodic test in Table K.4 shall be representative of the current production of the specified periods and shall be taken from the same rated voltage, class, and subclass. In subsequent periods, other case sizes in production shall be tested with the aim of covering the whole range of the approval.

No nonconforming items are permitted for Class Y capacitors in the voltage proof test.

K.3.4 Test schedule for qualification approval

The schedule for the lot-by-lot and periodic tests for quality conformance inspection is given in the relevant blank detail specification, for example, IEC 60384-14-1.

Table K.4 – Assessment level

<table>
<tr><th></th><th colspan="3">DZ</th></tr>
<tr><th>Inspection subgroup [b]</th><th>IL</th><th colspan="2">Acceptance number</th></tr>
<tr><td>A1</td><td>S-4</td><td colspan="2">0</td></tr>
<tr><td>A2</td><td>I</td><td colspan="2">0</td></tr>
<tr><td>B1</td><td>S-3</td><td colspan="2">0</td></tr>
<tr><th rowspan="2">Inspection subgroup [b]</th><th colspan="3">DZ</th></tr>
<tr><th>p</th><th>n</th><th>c [a]</th></tr>
<tr><td>C1A</td><td>6</td><td>6</td><td>0</td></tr>
<tr><td>C1B</td><td>6</td><td>12</td><td>0</td></tr>
<tr><td>C1</td><td>6</td><td>18</td><td>0</td></tr>
<tr><td>C2</td><td>6</td><td>12</td><td>0</td></tr>
<tr><td>C3:</td><td></td><td></td><td></td></tr>
<tr><td>Class X</td><td>3</td><td>12</td><td>0</td></tr>
<tr><td>Class Y</td><td>3</td><td>12</td><td>0</td></tr>
<tr><td>Lead-through</td><td>3</td><td>6</td><td>0</td></tr>
<tr><td>C4</td><td>6</td><td>6</td><td>0</td></tr>
<tr><td>C5</td><td>12</td><td>4</td><td>0</td></tr>
<tr><td>C6</td><td>12</td><td>6 to18</td><td>0</td></tr>
<tr><td>C7</td><td>12</td><td>24</td><td>0</td></tr>
<tr><td colspan="4">The sampling sizes corresponding to inspection levels should be selected from IEC 61193-2:2007, Table 1.</td></tr>
<tr><td colspan="4">IL = inspection level
p = periodicity in months
n = sample size
c = permissible number of nonconforming items</td></tr>
<tr><td colspan="4">[a] If one nonconforming item is obtained, all the tests of the group shall be repeated on a new sample and then no further nonconforming items are permitted.
[b] The content of the inspection subgroups is described in the relevant blank detail specification.
[c] The vibration, bump and shock tests in this subgroup are required to be carried out every 12 months only.</td></tr>
</table>

Annex X
(informative)

Cross-references to the previous edition of this document

The revision of this sectional specification has resulted in a new structure. Table X.1 and Table X.2 provide cross-references for all references to specific elements of the previous edition of this sectional specification.

Table X.1 – Reference to IEC 60384-14 for clause/subclause or annex

IEC 60384-14:2013 + AMD1:2016 4.1st edition Clause/Subclause or Annex	IEC 60384-1:20xx 5th edition Clause/Subclause or Annex	Notes
1 1.1 to 1.2	1	Scope and Object are merged into one in accordance with the ISO/IEC Directives Part 2
1.3	2	In accordance with ISO/IEC Directives Part 2
1.4	7 7.1	In accordance with the change of clause numbers. The hanging paragrah is avoided in accordance with ISO/IEC Directives Part 2.
1.4.1 to 1.4.3	7.2 to 7.4	In accordance with the change of clause numbers
1.4.4	6	This clause is merged into one
1.5	3.1	In accordance with ISO/IEC Directives Part 2
1.6	6 6.1 to 6.2	In accordance with the change of clause numbers. The hanging paragrah is avoided in accordance with ISO/IEC Directives Part 2.
1.6.1 to 1.6.3	6.3 to 6.5	In accordance with the change of clause numbers
1.7	3.2	In accordance with the change of clause numbers
1.7.1 to 1.7.2	3.2.1 to 3.2.2	In accordance with the change of clause numbers
2	4	In accordance with the change of clause numbers
2.1 to 2.3	4.1 to 4.3	In accordance with the change of clause numbers
3	8	In accordance with the change of clause numbers
3.1 to 3.4	8.1 to 8.4	In accordance with the change of clause numbers
3.4.2	Annex K	Text transferred to Annex K
3.5	8.5 8.5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
3.5.1 to 3.5.4	8.5.2 to 8.5.4	In accordance with the change of clause numbers
3.5.1.1	8.5.2.1 and K.3.2	Text modified and original copied to K.3.2
3.5.1.2	K.2.3	Text transferred to Annex K
3.5.2.2	K.3.4	Text transferred to Annex K
4	5 5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.1	5.2 5.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2	5.3	In accordance with the change of clause numbers

IEC 60384-14:2013 + AMD1:2016 4.1st edition **Clause/Subclause or Annex**	**IEC 60384-1:20xx 5th edition** **Clause/Subclause or Annex**	**Notes**
4.2.1	5.3.1 5.3.1.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2.1.1 to 4.2.1.4	5.3.1.2 to 5.3.1.5	In accordance with the change of clause numbers
4.2.2	5.3.2 5.3.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2.2.1 to 4.2.2.2	5.3.2.2 to 5.3.2.3	In accordance with the change of clause numbers
4.2.3 to 4.2.4	5.3.3 to 5.3.4	In accordance with the change of clause numbers
4.2.5	5.3.5 5.3.5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.2.5.1 to 4.2.5.2	5.3.5.2 to 5.3.5.3	In accordance with the change of clause numbers
4.3	5.4	In accordance with the change of clause numbers
4.4	5.5 6.5.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.4.1 to 4.4.2	5.5.2 to 5.5.3	In accordance with the change of clause numbers
4.5	5.6 5.6.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.5.1 to 4.5.2	5.6.2 to 5.6.3	In accordance with the change of clause numbers
4.6	5.7 5.7.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.6.1	5.7.2	In accordance with the change of clause numbers
4.7	5.8 5.8.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.7.1 to 4.7.2	5.8.2 to 5.8.3	In accordance with the change of clause numbers
4.8	5.9 5.9.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.8.1 to 4.8.2	5.9.2 to 5.9.3	In accordance with the change of clause numbers
4.9	5.10 5.10.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.9.1 to 4.9.2	5.10.2 to 5.10.3	In accordance with the change of clause numbers
4.10	5.11 5.11.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.10.1 to 4.10.2	5.11.2 to 5.11.3	In accordance with the change of clause numbers
4.11	5.12 5.12.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.11.1 to 4.11.6	5.12.2 to 5.12.7	In accordance with the change of clause numbers

IEC 60384-14:2013 + AMD1:2016 4.1st edition **Clause/Subclause or Annex**	**IEC 60384-1:20xx 5th edition** **Clause/Subclause or Annex**	**Notes**
4.12	5.13 5.13.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.12.1 to 4.12.3	5.13.2 to 5.13.4	In accordance with the change of clause numbers
4.13	5.14 5.14.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.13.1 to 4.13.3	5.14.2 to 5.14.4	In accordance with the change of clause numbers
4.14	5.15 5.15.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.14.1	5.15.2 5.15.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.14.1.1	5.15.2.2	In accordance with the change of clause numbers
4.14.2 to 4.14.7	5.15.3 to 5.15.8	In accordance with the change of clause numbers
4.15	5.16 5.16.1	In accordance with the change of clause numbers. The hanging paragrah is avoided in accordance with ISO/IEC Directives Part 2.
4.15.1 to 4.15.3	5.16.2 to 5.16.4	In accordance with the change of clause numbers
4.16 to 4.17	5.17 to 5.18	In accordance with the change of clause numbers
4.17.1	5.18.1 5.18.1.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.17.1.1	5.18.1.2	In accordance with the change of clause numbers
4.17.2	5.18.2 5.18.2.1	In accordance with the change of clause numbers. The hanging paragraph is avoided in accordance with ISO/IEC Directives Part 2.
4.17.2.1 to 4.17.2.2	5.18.2.2 to 5.18.2.3	In accordance with the change of clause numbers
4.18 to 4.20	5.19 to 5.21	In accordance with the change of clause numbers
Annex A to Annex I	Annex A to Annex I	No change
-	Annex J	New annex
3.4.2	Annnex K	New annex

Table X.2 indicates the new figure and table numbers with respect to IEC 60384-14:2013 + AMD1:2016 (4.1st edition).

Table X.2 – Reference to IEC 60384-14 for figure/table

IEC 60384-14:2013 + AMD1:2016 4.1st edition Figure/Table	**IEC 60384-14:20xx 5th edition Figure/Table**	**Notes**
Figure 1 to Figure 5	Figure 1 to Figure 5	No change
Figure 6	Figure 9	In accordance with the change of clause numbers
Figure 7 to Figure 9	Figure 6 to Figure 8	In accordance with the change of clause numbers
Table 3	Table 14	In accordance with the change of clause numbers
Table 4	Table K.1	Transferred to Annex K
Table 5 upper part	Table 15	Renumbered according to formation of Annex K
Table 5 lower part	Table K.2	Transferred to Annex K
Table 6	Table 16	Renumbered following the formation of Annex K
Table 7	Table K.3	Transferred to Annex K
Table 8	Table 17 and Table K4	Doubled in Annex K and renumbered following the formation of Annex K
–	Table 8	Unnumbered table numbered
Table 9 to Table 13	Table 3 to Table 7	In accordance with the change of clause numbers
Table 14 and Table 15	Table 9 and Table 10	In accordance with the change of clause numbers
-	Table 11	New table
Table 16 and Table 17	Table 12 and Table 13	In accordance with the change of clause numbers

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CONDENSATEURS FIXES UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRONIQUES –

Partie 14: Spécification intermédiaire – Condensateurs fixes pour la suppression des interférences électromagnétiques et la connexion au réseau d'alimentation

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L'IEC 60384-14 a été établie par le comité d'études 40 de l'IEC: Condensateurs et résistances pour équipements électroniques. Il s'agit d'une Norme internationale.

Cette cinquième édition annule et remplace la quatrième édition parue en 2013 et l'Amendement 1:2016. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) dans l'essai continu de chaleur humide, tous les types de condensateurs sont soumis à essai à la fois avec et sans tension assignée. Le nombre d'éprouvettes a été augmenté;
b) la tangente de l'angle de perte est ajoutée dans les essais du Groupe 0, dans les essais de sécurité uniquement;
c) l'homologation basée sur les essais de sécurité et de performance a été supprimée du corps du texte pour en faire une annexe normative;
d) la plage de tensions assignées est donnée au lieu des valeurs exactes de tension assignée;
e) une annexe normative de description des modèles de condensateurs et de la mesure des lignes de fuite et des distances d'isolement a été ajoutée;
f) l'importance des défaillances mécaniques (fissures) dans l'encapsulation des composants en tant que caractéristique de sécurité est mise en évidence dans les instructions de manipulation et les exigences après tous les essais pertinents.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
40/2985/FDIS	40/3022/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Une liste de toutes les parties de la série IEC 60384, publiées sous le titre général *Condensateurs fixes utilisés dans les équipements électroniques*, se trouve sur le site web de l'IEC.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

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CONDENSATEURS FIXES UTILISÉS DANS LES ÉQUIPEMENTS ÉLECTRONIQUES –

Partie 14: Spécification intermédiaire – Condensateurs fixes pour la suppression des interférences électromagnétiques et la connexion au réseau d'alimentation

1 Domaine d'application

La présente partie de l'IEC 60384 s'applique aux condensateurs et aux combinaisons condensateur/résistance destinés à être connectés à un réseau d'alimentation en courant alternatif ou à une autre alimentation dont la tension nominale ne dépasse pas 1 000 V c.a. (efficace) et dont la fréquence nominale ne dépasse pas 100 Hz. Le présent document inclut également des conditions et des exigences spécifiques supplémentaires pour la connexion aux alimentations en courant continu avec une tension assignée ne dépassant pas 1 500 V en courant continu.

La présente partie de l'IEC 60384 a pour principal objet de prescrire les valeurs assignées et caractéristiques préférentielles, de sélectionner, en se référant à l'IEC 60384-1, les procédures d'évaluation de la qualité appropriées, les essais et les méthodes de mesure et de donner les exigences de performances générales pour ce type de condensateur. Les sévérités et les exigences d'essai indiquées dans les spécifications particulières se rapportant à cette spécification intermédiaire présentent des niveaux de performances supérieurs ou égaux. Les niveaux de performance inférieurs ne sont pas autorisés.

Le présent document fournit un programme d'essais de sécurité à utiliser par les stations d'essai nationales dans les pays qui exigent une approbation par de telles stations.

Les catégories de surtension associées aux tensions d'alimentation alternatives pour les condensateurs classifiés dans le présent document doivent être issues de l'IEC 60664-1.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60060-1:2010, *Technique des essais à haute tension – Partie 1: Définitions et exigences générales*

IEC 60063, *Séries de valeurs normales pour résistances et condensateurs*

IEC 60068-1:2013, *Essais d'environnement – Partie 1: Généralités et lignes directrices*

IEC 60068-2-17, *Essais fondamentaux climatiques et de robustesse mécanique – Partie 2-17: Essais – Essai Q: Étanchéité*

IEC 60384-1:2021, *Condensateurs fixes utilisés dans les équipements électroniques – Partie 1: Spécification générique*

IEC 60664-1, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 60695-11-10, *Essais relatifs aux risques du feu – Partie 11-10: Flammes d'essai – Méthodes d'essai horizontal et vertical à la flamme de 50 W*

IEC 61193-2:2007, *Quality assessment systems – Part 2: Selection and use of sampling plans for inspection of electronic components and packages* (disponible en anglais seulement)

IEC 61210, *Dispositifs de connexion – Bornes plates à connexion rapide pour conducteurs électriques en cuivre – Exigences de sécurité*

CISPR 17, *Méthodes de mesure des caractéristiques d'antiparasitage des dispositifs de filtrage CEM passifs*

ISO 7000, *Symboles graphiques utilisables sur le matériel* (disponible à l'adresse http://www.graphical-symbols.info/equipment)

3 Termes et définitions et classification

3.1 Termes et définitions

Pour les besoins du présent document, les termes et les définitions de l'IEC 60384-1 ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

NOTE Certaines définitions de l'IEC 60384-1 ont été développées et font l'objet d'une note.

3.1.1
condensateur pour courant alternatif
condensateur conçu essentiellement pour fonctionner sous des tensions alternatives

Note 1 à l'article: Les condensateurs pour courant alternatif peuvent être utilisés avec des alimentations à courant continu de tension égale à la tension alternative efficace assignée du condensateur. Pour l'utilisation de condensateurs ayant une tension continue assignée supérieure à la tension alternative assignée, voir l'Annexe H.

3.1.2
condensateur d'antiparasitage
condensateur pour courant alternatif utilisé pour la réduction des perturbations électromagnétiques provoquées par les équipements électriques ou électroniques, ou par d'autres sources

3.1.3
condensateur de classe X
unité RC de classe X
condensateur ou unité RC d'un type approprié pour être utilisé dans des situations où une défaillance du condensateur ou de l'unité RC n'entraînerait pas de danger de choc électrique, mais pourrait être à l'origine d'un incendie

3.1.4
condensateur de classe Y
unité RC de classe Y
condensateur ou unité RC d'un type approprié pour être utilisé dans des situations où une défaillance du condensateur pourrait entraîner un danger de choc électrique

3.1.5
condensateur à deux bornes

condensateur d'antiparasitage doté de deux bornes

Note 1 à l'article: Voir Figure 1.

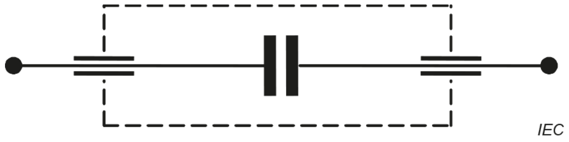


Figure 1 – Condensateur d'antiparasitage à deux bornes

3.1.6
unité RC série

combinaison fonctionnelle d'une résistance en série avec un condensateur de classe X ou Y

Note 1 à l'article: Voir Figure 2.

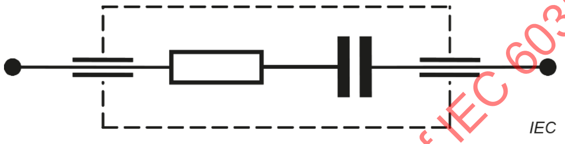


Figure 2 – Unité RC

Note 2 à l'article: Dans le présent document, lorsque le terme "condensateur" apparaît, il convient de comprendre les termes "condensateur ou unité RC" lorsque le contexte le permet.

3.1.7
condensateur de traversée

<coaxial> condensateur comprenant un conducteur central transportant un courant entouré d'un élément capacitif qui est lié symétriquement au conducteur central et au boîtier externe pour former une construction coaxiale

Note 1 à l'article: Ces condensateurs de traversée sont montés de manière coaxiale (voir Figure 3).

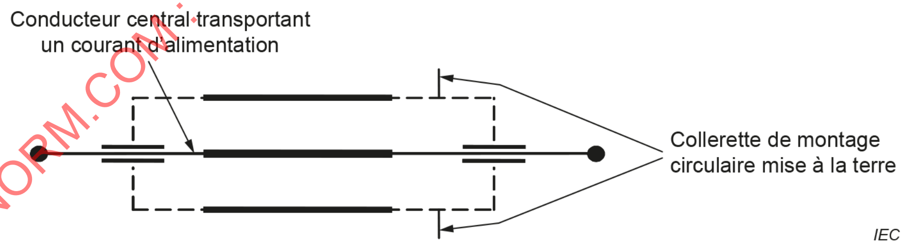
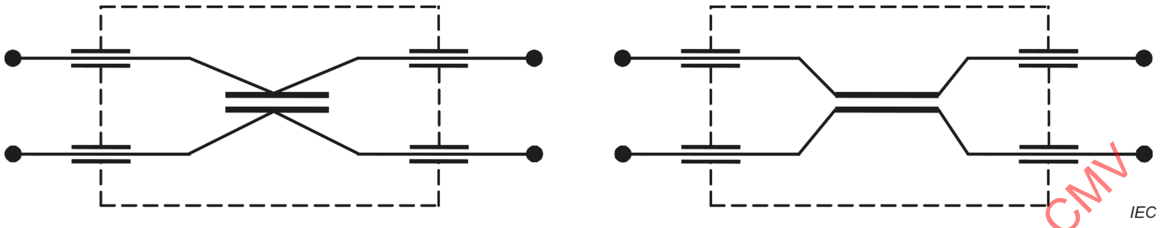


Figure 3 – Condensateur de traversée (coaxial)

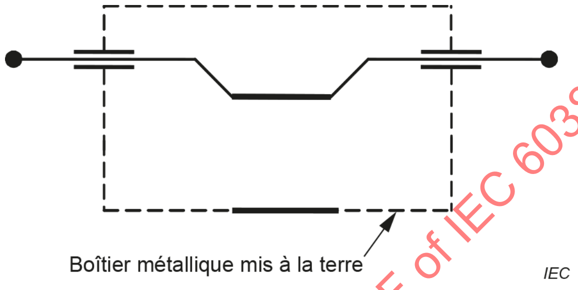
3.1.8
condensateur de traversée

<non coaxial> condensateur dans lequel les courants d'alimentation circulent à travers ou entre les bornes des électrodes

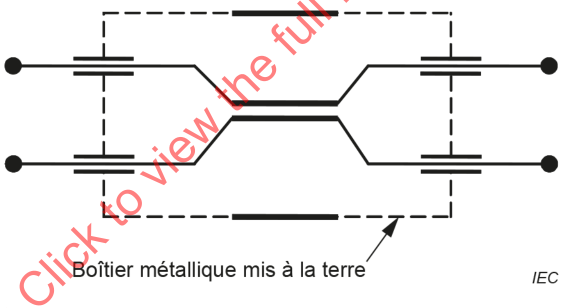
Note 1 à l'article: Voir Figure 4 a), Figure 4 b), Figure 4 c) et Figure 4 d).



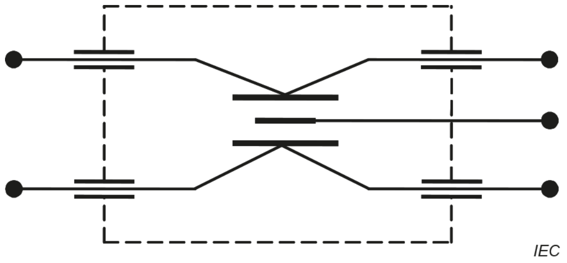
a) **Condensateur de traversée pour utilisation symétrique (non coaxial)**



b) **Condensateur de traversée pour utilisation asymétrique (non coaxial)**



c) **Condensateur de traversée à plusieurs unités pour utilisation symétrique et asymétrique (non coaxial)**



d) **Condensateur de traversée à plusieurs unités**

Figure 4 – Condensateurs de traversée

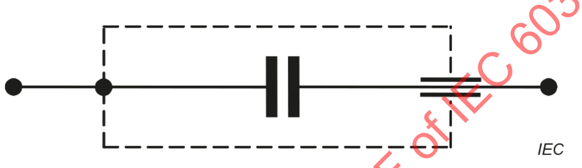
3.1.9
condensateur de contournement
condensateur dont les courants de perturbation radioélectrique sont shuntés

Note 1 à l'article: Il existe trois formes communes: condensateur simple, condensateurs connectés en triangle et condensateurs connectés en T. Le condensateur simple est constitué d'un condensateur dans un boîtier métallique avec une connexion de sortie connectée au boîtier comme à la Figure 5 a); la connexion en triangle est constituée d'un condensateur de classe X et de deux condensateurs de classe Y2 disposés en triangle comme représenté à la Figure 5 b); la connexion en T est constituée de trois condensateurs C_A, C_B et C_C connectés en T comme à la Figure 5 c).

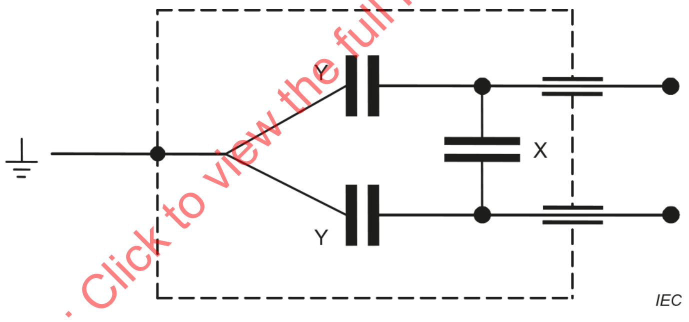
Les connexions en T et en triangle sont équivalentes électriquement (transformation étoile-triangle). Dans la connexion en T, le condensateur X est le résultat de la connexion en série de $C_B – C_C$ et les condensateurs de classe Y sont le résultat des connexions en série de $C_A – C_B$ et $C_A – C_C$.

Lorsque les condensateurs connectés en T sont soumis à des essais et lorsqu'il est indiqué que des tensions doivent être appliquées aux connexions de sortie des condensateurs de classe X, ces tensions doivent être appliquées entre la connexion de sortie de ligne (L) et la connexion de sortie de neutre (N). De manière similaire, lorsqu'il est indiqué que des tensions doivent être appliquées aux connexions de sortie des condensateurs de classe Y, ces tensions doivent être appliquées entre la connexion de sortie de ligne et la connexion de sortie de neutre connectées ensemble et la connexion de sortie de terre.

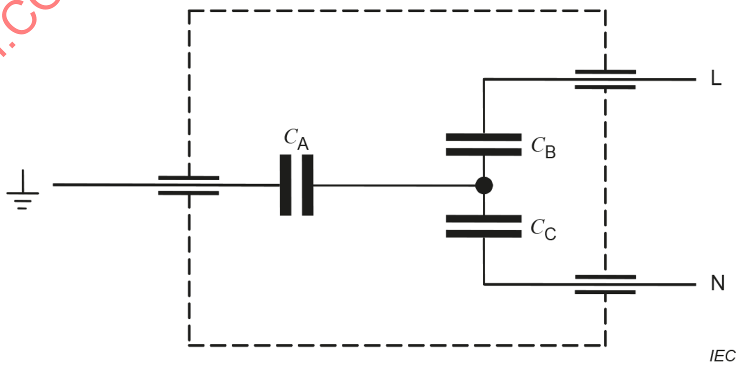
Note 2 à l'article: Voir Figure 5 a), Figure 5 b) et Figure 5 c)



a) Condensateur de contournement simple



b) Condensateur de contournement en triangle (en boîtier métallique)



c) Exemple de condensateurs de contournement connectés en T (en boîtier non métallique)

NOTE Pour les condensateurs dotés de boîtiers non métalliques, la connexion à la terre est une connexion de sortie distincte comme représenté à la Figure 5 c).

Figure 5 – Condensateurs de contournement

3.1.10
tension assignée

<pour le condensateur> tension de fonctionnement efficace à la fréquence assignée, ou tension continue de fonctionnement qui peut être appliquée en continu aux connexions de sortie d'un condensateur à n'importe quelle température entre la température minimale de catégorie et la température maximale de catégorie

Note 1 à l'article: Ceci implique, pour les condensateurs couverts par le présent document, que la tension de catégorie est la même que la tension assignée.

3.1.11
tension continue assignée

U_R c.c.

tension continue maximale de fonctionnement pouvant être appliquée en permanence aux connexions de sortie d'un condensateur à toute température comprise entre la température minimale de catégorie et la température maximale de catégorie

Note 1 à l'article: Ce terme et cette désignation (U_R c.c.) sont utilisés uniquement pour un condensateur spécifié avec une tension continue assignée dépassant sa tension alternative assignée (efficace).

3.1.12
puissance assignée

<d'une unité RC série> puissance maximale qui peut être dissipée par l'unité RC à la température assignée pendant un fonctionnement continu

3.1.13
température maximale de catégorie

température maximale de la surface pour laquelle le condensateur a été conçu pour un fonctionnement en continu

Note 1 à l'article: Pour des condensateurs de traversée et des unités RC série, la température de surface externe peut être affectée par l'échauffement interne dû au courant traversant. Les connexions de sortie d'un condensateur sont considérées comme faisant partie de la surface externe.

Note 2 à l'article: Cette définition remplace celle donnée dans l'IEC 60384-1:2021, 3.41, parce que les condensateurs d'antiparasitage conformes au présent document sont destinés à être connectés au réseau d'alimentation et peuvent générer un échauffement interne.

3.1.14
température minimale de catégorie

température minimale de la surface pour laquelle le condensateur a été conçu pour un fonctionnement en continu

Note 1 à l'article: Cette définition remplace celle donnée dans l'IEC 60384-1:2021, 3.10.

3.1.15
température assignée

<d'un condensateur de traversée ou d'une unité RC série> température ambiante maximale à laquelle un condensateur de traversée peut transporter son courant traversant assigné ou à laquelle une unité RC série peut dissiper sa puissance assignée

Note 1 à l'article: Cette définition remplace celle donnée dans l'IEC 60384-1:2021, 3.24.

3.1.16
perte d'insertion

<pour les condensateurs> rapport des tensions avant et après l'insertion du dispositif d'antiparasitage, mesurées au niveau des connexions de sortie

Note 1 à l'article: Lorsqu'elle est mesurée en décibels, la perte d'insertion est égale à 20 fois le logarithme décimal du rapport indiqué.

3.1.17
courant assigné du conducteur
<d’un condensateur de traversée>, courant maximal admissible traversant les conducteurs du condensateur à la température assignée pendant un fonctionnement continu

3.1.18
fréquence de résonance principale
<d’un condensateur à deux bornes>, plus petite fréquence à laquelle l’impédance du condensateur est minimale lorsqu’une tension sinusoïdale est appliquée

3.1.19
tension de choc
tension transitoire périodique d’une forme d’onde définie comme cela est décrit dans l’IEC 60060-1

3.1.20
inflammabilité passive
aptitude d’un condensateur à brûler avec une flamme par suite de l’application d’une source de chaleur externe

3.1.21
inflammabilité active
aptitude d’un condensateur à brûler avec une flamme par suite d’une charge électrique

3.1.22
condensateur pour montage en surface
condensateur dont les petites dimensions et la nature de la forme des connexions de sortie en font un condensateur pouvant être monté en surface dans des circuits hybrides et sur des cartes imprimées

3.2 Classifications

3.2.1 Classification des condensateurs de classe X

Les condensateurs de classe X sont divisés en deux sous-classes (voir Tableau 1) en fonction de la tension de crête des chocs superposée à la tension d’alimentation auxquelles ils peuvent être soumis en service. De tels chocs peuvent être engendrés par la foudre qui tombe sur des lignes extérieures, par des commutations dans des équipements du voisinage ou par des commutations dans l’équipement dans lequel le condensateur est utilisé.

Tableau 1 – Classification des condensateurs de classe X

Sous-classe	**Tension de choc de crête en service**	**Application**	**Tension de choc de crête U_P appliquée avant l'essai d'endurance**	
			$C_N \leq 1{,}0\ \mu F$	$C_N > 1{,}0\ \mu F$
X1	> 2,5 kV ≤ 4,0 kV	Application pour impulsions de haute tension	4 kV	$U_P = \frac{4}{\sqrt{\frac{C_N}{10^{-6}\ F}}}$ in kV
X2	≤ 2,5 kV	Usage général	2,5 kV	$U_P = \frac{2{,}5}{\sqrt{\frac{C_N}{10^{-6}\ F}}}$ in kV

Les condensateurs de classe X1 peuvent être remplacés par des condensateurs de classe Y2 ou Y1 de tension assignée U_R supérieure ou égale. Les condensateurs de classe X2 peuvent être remplacés par des condensateurs de classe X1, Y2 ou Y1 de tension assignée, U_R, supérieure ou égale.

NOTE 1 Le facteur utilisé pour la réduction de U_P pour les valeurs de capacité supérieures à 1,0 F maintient $0{,}5 \times C_N U_P^2$ constante pour ces valeurs de capacité; C_N est exprimé en F.

NOTE 2 L'IEC 60664-1 donne les catégories de surtension liées à une tension de choc assignée et à une tension d'alimentation assignée.

3.2.2 Classification des condensateurs de classe Y

Les condensateurs de classe Y sont encore divisés en trois sous-classes: Y1, Y2 et Y4, comme indiqué dans le Tableau 2.

Tableau 2 – Classification des condensateurs de classe Y

Sous-classe	**Type d'isolation en pont**	**Gamme de tensions assignées**	**Tension de choc de crête U_P appliquée avant l'essai d'endurance**	
Y1	Double isolation ou isolation renforcée	≤ 500 V	8,0 kV	
Y2	Isolation principale ou isolation supplémentaire	≥ 150 V ≤ 500 V	$C_N \leq 1{,}0\ \mu F$	$C_N > 1{,}0\ \mu F$
			5 kV	$U_P = \frac{5}{\sqrt{\frac{C_N}{10^{-6}\ F}}}$ kV
Y4	Isolation principale ou isolation supplémentaire	< 150 V	2,5 kV	

Les condensateurs de classe Y2 peuvent être remplacés par des condensateurs de classe Y1 de tension assignée, U_R, supérieure ou égale.

NOTE 1 Les définitions d'isolation principale, supplémentaire, double et renforcée sont données dans l'IEC 61140.

NOTE 2 Le facteur utilisé pour la réduction de U_P pour les valeurs de capacité supérieures à 1,0 F maintient $0{,}5 \times C_N U_P^2$ constante pour ces valeurs de capacité; C_N est exprimé en F.

NOTE 3 L'IEC 60664-1 donne les catégories de surtension liées à une tension de choc assignée et à une tension d'alimentation assignée.

Un condensateur Y1 peut relier une double isolation ou une isolation renforcée.

Le boîtier d'un condensateur de classe Y1 ne doit pas contenir d'autres composants.

Des ensembles, tels que des condensateurs de contournement connectés en T ou en triangle, peuvent être construits à partir de condensateurs de classe Y ou de condensateurs de classe X, à condition que ces condensateurs satisfassent aux exigences des sous-classes X et Y applicables.

Un condensateur de classe Y peut relier en pont une isolation principale. Un condensateur de classe Y peut relier en pont une isolation supplémentaire. Si la combinaison d’une isolation principale et d’une isolation supplémentaire est reliée par au moins deux condensateurs de classe Y2 ou Y4 en série, ils doivent appartenir aux mêmes classes et sous-classes, avoir la même tension assignée et avoir la même valeur de capacité nominale.

4 Valeurs assignées et caractéristiques préférentielles

4.1 Catégories climatiques préférentielles

Il convient de choisir les valeurs données dans les spécifications particulières de préférence dans le présent alinéa.

Les condensateurs couverts par le présent document sont classés en catégories climatiques selon les règles générales données dans l’IEC 60068-1:2013, Annexe A.

Les températures minimale et maximale de catégorie et la durée de l’essai continu de chaleur humide doivent être sélectionnées dans la liste ci-dessous:

- température minimale de catégorie: –65 °C, –55 °C, –40 °C, –25 °C et –10 °C;
- température maximale de catégorie: +85 °C, +100 °C, +105 °C, +110°C, +125 °C et +155 °C;
- durée de l’essai continu de chaleur humide: 21 jours et 56 jours.

Les sévérités pour les essais à froid et de chaleur sèche sont les températures minimale et maximale de catégorie respectivement.

L’IEC 60940:2015 donne des recommandations sur l’application des catégories décrites ci-dessus.

4.2 Valeurs assignées préférentielles

4.2.1 Capacité nominale (C_N)

Les valeurs préférentielles de capacité nominale sont:

1, 1,5, 2,2, 3,3, 4,7, 6,8 et leurs multiples décimaux.

Ces valeurs sont conformes à la série E6 de valeurs préférentielles données dans l’IEC 60063.

4.2.2 Tolérance sur la capacité nominale

La tolérance maximale pour la capacité nominale est de ± 20 %.

4.2.3 Choix des tensions assignées (U_R)

La gamme de tensions alternatives assignées est comprise entre 125 V et 1 000 V.

La gamme de tensions continues assignées est comprise entre 125 V et 1 500 V.

Il convient de choisir les condensateurs d'antiparasitage de telle sorte que leur tension assignée soit supérieure ou égale à la tension nominale du système d'alimentation auquel ils sont connectés. La conception des condensateurs doit prendre en compte la possibilité que la tension du système peut augmenter jusqu'à dépasser de 10 % sa tension nominale. Dans une connexion en étoile, la tension maximale sur les condensateurs doit être calculée dans le cas le plus défavorable lorsque les tolérances sur les capacités nominales des condensateurs utilisés sont prises en considération.

4.2.4 Résistance nominale (R_N)

Les valeurs préférentielles de résistance nominale doivent être choisies dans la série E6 de l'IEC 60063.

4.2.5 Température assignée

La température assignée des condensateurs de traversée et des unités RC série ne doit pas être inférieure à +40 °C.

4.2.6 Inflammabilité passive

La catégorie préférentielle d'inflammabilité passive autorisée est la catégorie B (voir 5.18). L'utilisation de la catégorie C doit faire l'objet d'un accord entre le fournisseur du composant et le client. Voir également 5.18 pour des essais alternatifs d'inflammabilité passive.

Dérogation: pour les composants dont le volume est inférieur à 1 750 mm^3, la catégorie C d'inflammabilité passive est autorisée.

NOTE Les catégories d'inflammabilité passive supérieures à la catégorie C peuvent exiger des additifs ignifuges qui peuvent être considérés comme ayant des incidences sur l'environnement. Ces catégories sont soumises à négociation entre les fabricants et les clients pour trouver un compromis entre les exigences environnementales et les exigences de sécurité.

4.3 Exigences sur les manchons, les bandes, les tubes et l'isolation des fils

Les manchons, les bandes, les tubes et l'isolation des fils utilisés dans les composants conformes au présent document doivent être assignés pour la tension impliquée et la température atteinte dans n'importe quelle condition d'utilisation réelle. Les manchons, les tubes et l'isolation des fils doivent avoir une classe d'ignifugation assignée VW1. Le ruban adhésif doit être ignifuge.

Si des bornes isolées sont exigées, il convient que les couleurs préférentielles soient transparentes ou blanches.

5 Procédures d'essai et de mesure, et exigences de performances

5.1 Généralités

Cet article complète les informations de l'IEC 60384-1:2021, de l'Article 4 à l'Article 10.

Des essais en courant alternatif réalisés à une fréquence comprise entre 50 Hz et 100 Hz sont considérés valides pour n'importe quelle fréquence nominale comprise entre 50 Hz et 100 Hz. En cas de doute, 50 Hz doit être la fréquence de référence pour les mesures.

Pendant la manipulation, l'essai et l'inspection, tout dommage involontaire de l'isolation sur le corps et les sorties du composant doit être évité. Les instructions de manipulation fournies par le fabricant doivent être respectées.

5.2 Examen visuel et contrôle des dimensions

5.2.1 Généralités

Voir l'IEC 60384-1:2021, 7.1, avec les détails supplémentaires de 5.2.2.

5.2.2 Lignes de fuite et distances d'isolement

Les lignes de fuite et les distances d'isolement sur l'extérieur du condensateur entre les parties sous tension de polarité différente ou entre les parties sous tension et un boîtier métallique ne doivent pas être inférieures aux valeurs appropriées indiquées dans le Tableau 3.

Le Tableau 3 est basé sur l'IEC 60664-1, mais les normes de sécurité des équipements IEC 60335-1 et IEC 62368-1 ont également été prises en compte. Des informations complémentaires peuvent être obtenues dans l'IEC 60664-1.

Le Tableau 3 est généré en utilisant les conditions environnementales suivantes comme lignes directrices principales:

degré de pollution 2, altitude ≤ 2 000 m et indice de résistance au cheminement (IRC) des matériaux ≥ 100.

Des lignes de fuite inférieures à celles indiquées dans le Tableau 3 peuvent être utilisées si les règles données dans l'IEC 60664-1 pour l'IRC des matériaux des composants l'autorisent. Une ligne de fuite doit toujours être supérieure ou égale à la distance d'isolement indiquée dans ce tableau. Les normes d'équipement peuvent exiger des distances supérieures à celles données ici.

La conformité doit être contrôlée par des mesures conformément aux règles établies dans l'IEC 60664-1 pour les mesures sur l'extérieur du condensateur. D'autres exigences peuvent être nécessaires, par exemple pour des condensateurs destinés à être utilisés dans d'autres environnements que le degré 2 de pollution (par exemple des condensateurs protégés contre les projections et protégés contre les gouttes) ou pour des condensateurs utilisés à des altitudes supérieures à 2 000 m. Des recommandations sont données dans l'IEC 60664-1.

Tableau 3 – Lignes de fuite et distances d'isolement

Points de mesure	Tension assignée (efficace)									
	$U_R \le 130$ V		130 V < $U_R \le 250$ V		250 V < $U_R \le 500$ V		500 V < $U_R \le 760$ V		760 V < $U_R \le 1\,000$ V	
	Ligne de fuite mm	Distance d' isolement mm	Ligne de fuite mm	Distance d' isolement mm	Ligne de fuite mm	Distance d' isolement mm	Ligne de fuite mm	Distance d' isolement mm	Ligne de fuite mm	Distance d' isolement mm
Entre des parties sous tension de polarité différente (isolation fonctionnelle) [a]	2,0	1,5	3,0	2,5	4,0	3,0	6,3	5,5	8,0	5,5
Entre des parties sous tension et d'autres parties métalliques sur une isolation principale [b]	2,0	1,5	4,0	3,0	5,0	4,0	6,3	5,5	8,0	7,5
Entre des parties sous tension et d'autres parties métalliques sur une isolation renforcée [c]	8,0	8,0	8,0	8,0	10,0	8,0	12,6	11,0	16,0	11,0

NOTE Les valeurs d'isolation renforcée pour des tensions supérieures à > 500 V sont données à titre d'information uniquement. Dans la présente norme, les condensateurs de classe Y1 sont limités à 500 V.

[a] Ces limites doivent être utilisées pour les mesures entre les bornes d'un condensateur de classe X.

[b] Ces limites doivent être utilisées pour les mesures entre chaque borne et le boîtier métallique d'un condensateur de classe X et pour les mesures entre les bornes ou entre chaque borne et le boîtier métallique d'un condensateur de classe Y2 ou Y4.

[c] Ces limites doivent être utilisées pour les mesures entre les bornes d'un condensateur de classe Y1 (jusqu'à 500 V).

L'Annexe J décrit différents modèles de condensateurs et la façon dont les lignes de fuite et les distances d'isolement sont mesurées pour ceux-ci. Des précautions exigées pour la manipulation des condensateurs, par exemple lorsque les sorties sont pliées, sont également décrites.

5.3 Essais électriques

5.3.1 Tension de tenue

5.3.1.1 Généralités

Voir l'IEC 60384-1:2021, 6.2, avec les détails de 5.3.1.2 à 5.3.1.5.

5.3.1.2 Circuit d'essai pour les essais en courant continu

Omettre le condensateur C_1 si le condensateur en essai, ou une partie de celui-ci, est un condensateur à film métallisé ou au papier métallisé.

Le produit de R_1 et (C_1 + C_X) doit être inférieur ou égal à 1 s et supérieur à 0,01 s.

R_1 inclut la résistance interne de l'alimentation.

R_2 doit limiter le courant de décharge à une valeur inférieure ou égale à 0,05 A.

5.3.1.3 Circuit et méthode d'essai pour les essais en courant alternatif

Lorsqu'une tension à 50/60 Hz est appliquée pour les essais d'homologation et les essais périodiques, la tension doit être délivrée par un transformateur alimenté par un autotransformateur variable et la tension doit être augmentée depuis une valeur proche de zéro jusqu'à la tension d'essai à une vitesse ne dépassant pas 150 V/s. Le temps d'essai doit être compté à partir du moment où la tension d'essai est atteinte. A la fin du temps d'essai, la tension d'essai doit être réduite jusqu'à une valeur proche de zéro et le condensateur déchargé à travers une résistance appropriée.

Pour des essais lot par lot et à 100 %, la tension doit être appliquée directement à la tension d'essai totale, mais il convient d'éviter les crêtes de surtension.

5.3.1.4 Tension appliquée

Les tensions du Tableau 4 doivent être appliquées entre les points de mesure respectifs montrés dans l'IEC 60384-1:2021, Tableau 3, pendant une période de 1 min pour les essais d'homologation et les essais périodiques et pendant une période d'au moins 1 s pour les essais lot par lot de conformité de la qualité, avec les détails suivants:

a) l'essai selon 2c de l'IEC 60384-1:2021, Tableau 3, ne doit pas être effectué;

b) pour les unités encapsulées en boîtier non métallique, un essai de tension de tenue tel que l'essai C doit être effectué uniquement pour les essais d'homologation et les essais périodiques;

c) la méthode consistant à appliquer la tension d'essai pour l'essai C doit être indiquée dans la spécification particulière. Pour les essais de qualification, la méthode de la feuille métallique donnée dans l'IEC 60384-1:2021, 6.2.3.4, doit être utilisée, sauf indication contraire dans la spécification particulière;

   NOTE Cet essai est uniquement applicable aux condensateurs isolés en boîtier non métallique ou en boîtier métallique isolé. Voir l'IEC 60384-1:2021, 6.6.3.4.

d) pour les essais de longueur comprise entre 1 s et 2 s, la tension du Tableau 4 doit être augmentée comme indiqué à la Figure 9;

e) lorsqu'un condensateur est homologué pour des applications en courant continu conformément à l'Annexe H, la tension d'essai calculée conformément au Tableau H.1 pour l'essai de tension de tenue A doit être appliquée pour les essais lot par lot (100 %) et les essais de qualification, si sa valeur est supérieure à la valeur déterminée conformément au Tableau 4.

L'attention est attirée sur le fait que la répétition de l'essai de tension de tenue par l'utilisateur peut endommager le condensateur. Si l'utilisateur répète l'essai de tension de tenue, il convient que la tension appliquée ne dépasse pas 66 % de la tension d'essai spécifiée dans le Tableau 4.

Tableau 4 – Tension de tenue

Classe	Gamme de tensions assignées	Essai A[d]	Essai B ou essai C
X1 X2	≤ 1 000 V	4,3 U_R (c.c.) [c]	2 U_R + 1 500 V (courant alternatif) avec au moins 2 000 V (courant alternatif) [a]
Y1	≤ 500 V	4 000 V (c.a.)	4 000 V (c.a.)
Y2	≥ 150 V ≤ 500 V	U_R + 1 200 V (courant alternatif) avec au moins 1 500 V (courant alternatif) [b]	2 U_R + 1 500 V (courant alternatif) avec au moins 2 000 V (courant alternatif) [b]
Y4	< 150 V	900 V (c.a.) [b]	900 V (c.a.) [b]

[a] Pour les unités de condensateurs connectés en étoile ou en T conformément à la Figure 5b et à la Figure 5c, la tension d'essai entre bornes et boîtier doit être la tension d'essai appropriée pour les condensateurs de classe Y.

[b] Pour les essais lot par lot de condensateurs des classes Y2 et Y4, la tension alternative d'essai peut être remplacée par une tension continue égale à 1,5 fois la tension alternative prescrite.

[c] L'U_R de cet essai en courant continu est égale à la valeur de la tension alternative assignée.

[d] Pour les condensateurs homologués conformément à l'Annexe H, voir 5.3.1.4 e).

5.3.1.5 Exigences

Aucun claquage permanent ni contournement ne doit être constaté pendant la période d'essai.

NOTE La présence de claquages autocicatrisants pendant l'application des tensions d'essai sur les condensateurs à films métalliques est autorisée.

Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées).

5.3.2 Capacité

5.3.2.1 Généralités

Voir l'IEC 60384-1:2021, 6.3, avec les détails de 5.3.2.2 et 5.3.2.3.

5.3.2.2 Conditions de mesure

La capacité mesurée doit être la capacité série équivalente.

La fréquence de mesure doit être de 1 kHz, mais elle doit être de 1 MHz pour les condensateurs en céramique avec C_N < 100 pF (classe 2) et C_N ≤ 1 000 pF (classe 1).

La température de mesure doit être conforme à l'IEC 60384-1:2021, 5.2.1.

La tension de mesure ne doit pas dépasser la tension assignée. Pour les condensateurs en céramique, la tension de mesure doit être égale à (1,0 ± 0,2) V.

Puisque la capacité nominale des condensateurs en céramique, telle que mesurée ci-dessus, est la capacité pour signaux faibles, le fabricant doit fournir les informations suivantes pour les condensateurs en céramique:

a) le courant maximal 50/60 Hz attendu traversant le condensateur à la tension assignée en tenant compte de la tolérance de la capacité et de la caractéristique (ou du coefficient) de température de la capacité;

b) la capacité minimale attendue en tenant compte de la tolérance de la capacité et de la caractéristique (ou du coefficient) de température de la capacité.

5.3.2.3 Exigences

La capacité doit se situer dans la tolérance spécifiée.

5.3.3 Tangente de l’angle de perte

Cet essai est normalement exigé pour les condensateurs métallisés et en céramique uniquement.

Voir l’IEC 60384-1:2021, 6.4, avec les détails suivants:

La fréquence de mesure doit être de 10 kHz pour $C_N \leq 1$ µF et 1 kHz pour $C_N > 1$ µF. Pour les condensateurs céramiques, la fréquence de mesure doit être de 1 kHz, mais pour les condensateurs avec $C_N < 100$ pF (classe 2) et $C_N \leq 1\,000$ pF (classe 1), la fréquence de mesure doit être de 1 MHz.

5.3.4 Résistance [résistance série équivalente (RSE)] (pour des unités RC seulement)

La RSE doit être mesurée dans un circuit équivalent série à la fréquence suivante:

100 kHz pour $R_N \times C_N < 50$ µs;

1 kHz pour $R_N \times C_N \geq 50$ µs

où

R_N est la résistance nominale en ohms, et

C_N est la capacité nominale en farads.

5.3.5 Résistance d’isolement

5.3.5.1 Généralités

Voir l’IEC 60384-1:2021, 6.1, avec les détails de 5.3.5.2 et 5.3.5.3.

Dans les essais lot par lot de conformité de la qualité, la mesure peut être interrompue lorsque la valeur de la résistance d’isolement dépasse les limites du Tableau 5 ou du Tableau 6, ce qui peut se produire avant 60 s.

5.3.5.2 Correction de la température

Lorsque cela est indiqué dans la spécification particulière, la température à laquelle la mesure est réalisée doit être notée. Si cette température diffère de 20 °C, une correction doit être apportée à la valeur mesurée en multipliant cette valeur par le facteur de correction approprié indiqué dans la spécification intermédiaire pour le diélectrique concerné, ou elle est donnée dans la spécification particulière.

5.3.5.3 Exigences

La résistance d’isolement doit dépasser les valeurs du Tableau 5 ou du Tableau 6, suivant le cas.

Tableau 5 – Résistance d'isolement – Essais de sécurité uniquement

Essai A		Essai B ou essai C
Lorsque C_N > 0,33 µF RC_N en s	Lorsque C_N ≤ 0,33 µF R en MΩ	R en MΩ
2 000 [a, b]	6 000	6 000

- C_N est la capacité nominale et R la résistance d'isolement mesurée.
- Des limites plus sévères et liées au diélectrique peuvent être données dans la spécification particulière pour les essais de performances seulement, si possible en se référant à la publication IEC appropriée.
- Pour des condensateurs ayant une connexion de sortie connectée au boîtier, il convient d'utiliser les limites de la résistance d'isolement pour l'essai A.

  Pour des condensateurs avec une résistance de décharge, il convient d'effectuer la mesure avec la résistance de décharge débranchée. Si la résistance ne peut pas être débranchée sans détruire le condensateur, il convient d'omettre l'essai dans le groupe A; et, pour les essais d'homologation et les essais périodiques, il convient de réaliser l'essai sur la moitié des spécimens dans l'échantillon; il convient que l'échantillon soit constitué de condensateurs réalisés spécialement sans résistance de décharge.

[a] Également pour diélectriques en plastique et papier mélangés.

[b] Pour les condensateurs avec diélectrique en papier imbibé d'ester, les valeurs du tableau doivent être remplacées respectivement par les valeurs 500, 1 500 et 2 000.

Tableau 6 – Résistance d'isolement – Essais de sécurité et de performances

Diélectrique	Essai A		Essai B ou essai C
	Lorsque C_N > 0,33 µF RC_N en s	Lorsque C_N ≤ 0,33 µF R en MΩ	R en MΩ
Papier [a, b]	2 000	6 000	6 000
Plastique	5 000	15 000	30 000
Céramique	–	6 000	3 000

- C_N est la capacité nominale et R la résistance d'isolement mesurée.
- Des limites plus sévères et liées au diélectrique peuvent être données dans la spécification particulière pour les essais de performances seulement, si possible en se référant à la publication IEC appropriée.
- Pour des condensateurs ayant une connexion de sortie connectée au boîtier, il convient d'utiliser les limites de la résistance d'isolement pour l'essai A.
- Pour des condensateurs avec une résistance de décharge, il convient d'effectuer la mesure avec la résistance de décharge débranchée. Si la résistance ne peut pas être débranchée sans détruire le condensateur, il convient d'omettre l'essai dans le groupe A; et, pour les essais d'homologation et les essais périodiques, il convient de réaliser l'essai sur la moitié des spécimens dans l'échantillon; il convient que l'échantillon soit constitué de condensateurs réalisés spécialement sans résistance de décharge.

[a] Également pour diélectriques en plastique et papier mélangés.

[b] Pour les condensateurs avec diélectrique en papier imbibé d'ester, les valeurs du tableau doivent être remplacées respectivement par les valeurs 500, 1 500 et 2 000.

5.4 Robustesse des connexions de sortie

Voir l'IEC 60384-1:2021, 7.3, avec les détails suivants.

La méthode d'essai et le degré de sévérité à utiliser doivent être spécifiés dans la spécification particulière.

L'essai pour des contacts à enclenchement doit être spécifié dans la spécification particulière; les méthodes d'essai et la sévérité doivent être conformes aux articles applicables de l'IEC 61210.

L'essai doit être réalisé avec soins conformément aux instructions, afin que le revêtement du condensateur ne soit pas rompu en raison d'une mauvaise manipulation du composant. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées).

5.5 Résistance à la chaleur de brasage

5.5.1 Généralités

Cet essai ne s'applique pas aux condensateurs avec des conducteurs isolés de longueur supérieure à 10 mm ni aux condensateurs avec des connexions de sortie non destinées à être brasées (par exemple des connexions de sortie à vis et des connexions de sortie rapides).

Lorsque le préconditionnement est effectué, les mesures initiales doivent être réalisées après le préconditionnement.

Lorsque, pour des condensateurs fixes à diélectrique en céramique de Classe 2, une mesure précise de la dérive de capacité est exigée, il convient d'effectuer un préconditionnement selon les conseils du fabricant (voir Annexe G).

Voir l'IEC 60384-1:2021, 9.1, avec les détails de 5.5.2 et 5.5.3.

5.5.2 Conditions d'essai

Il ne doit pas y avoir de préséchage.

5.5.3 Exigences, mesures et inspection finales

Les mesures finales après cet essai sont les mesures intermédiaires après les essais du sous-groupe 1A et avant le reste des essais du groupe 1. Les condensateurs doivent faire l'objet d'un examen visuel et être mesurés. Ils doivent satisfaire aux exigences du Tableau 7.

Tableau 7 – Résistance à la chaleur de brasage – Exigences

Inspection ou mesure	Méthode d'inspection ou de mesure	Exigences
Examen visuel	5.2	Aucun dommage visible. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées).
Capacité	5.3.2	La différence entre la capacité mesurée finalement et dans le groupe 0 du Tableau 14 ou du Tableau 15 ne doit pas dépasser 5 % [a]
Résistance (le cas échéant)	5.3.4	$\lvert \Delta R/R \rvert \leq 5$ %

[a] Pour les condensateurs en céramique, la différence de capacité ne doit pas dépasser 10 %.

5.6 Brasabilité

5.6.1 Généralités

Cet essai ne s'applique pas aux condensateurs avec des connexions de sortie non destinées au brasage (telles que les connexions de sortie à vis et les contacts à enclenchement).

Voir l'IEC 60384-1:2021, 9.2, avec les détails de 5.6.2 et 5.6.3.

5.6.2 Conditions d'essai

Pas de vieillissement exigé.

Les brasures préférentielles, leur température du bain de brasage et leur temps de processus:

- brasure Sn96,5Ag3Cu,5: (245 ± 3) °C pendant (3 ± 0,3) s;
- brasure Sn99,3Cu,7: (250 ± 3) °C pendant (3 ± 0,3) s.

Quand la méthode 2 est utilisée, un fer à souder de taille A doit être utilisé.

5.6.3 Exigences

Voir Tableau K.3.

5.7 Variations rapides de température

5.7.1 Généralités

Lorsque, pour des condensateurs fixes à diélectrique en céramique de Classe 2, une mesure précise de la dérive de capacité est exigée, il convient d'effectuer un préconditionnement selon les conseils du fabricant (voir Annexe G).

Lorsque le préconditionnement est effectué, les mesures initiales doivent être réalisées après le préconditionnement.

Voir l'IEC 60384-1:2021, 8.1 avec les détails suivants:

- nombre de cycles: 5;
- durée d'exposition aux limites de température: au moins 30 min.

5.7.2 Inspection finale

Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées).

5.8 Vibrations

5.8.1 Généralités

Voir l'IEC 60384-1:2021, 7.4, avec les détails de 5.8.2 et 5.8.3.

5.8.2 Conditions d'essai

Le degré de sévérité suivant de l'essai Fc s'applique: 0,75 mm de déplacement ou 100 m/s^2, selon l'amplitude la plus basse, sur l'une des plages de fréquences suivantes: 10 Hz à 55 Hz, 10 Hz à 500 Hz, 10 Hz à 2 000 Hz. La durée totale doit être de 6 h.

La spécification particulière doit spécifier la plage de fréquences et doit également spécifier la méthode de montage à utiliser. Pour les condensateurs à sorties axiales destinés à être montés par leurs connecteurs de sortie, la distance entre le corps et le point de montage doit être égale à (6 ± 1) mm.

5.8.3 Inspection finale

Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées).

5.9 Chocs répétitifs (secousses)

5.9.1 Généralités

La spécification particulière doit indiquer si l'essai de chocs ou de secousses s'applique.

Voir l'IEC 60384-1:2021, 7.5, avec les détails de 5.9.2 et 5.9.3.

5.9.2 Conditions d'essai

Les sévérités suivantes sont les sévérités préférentielles:

- nombre total de secousses: 1 000 ou 4 000;
- accélération: 400 m/s^2;
- durée des impulsions: 6 ms.

La méthode de montage et la sévérité doivent être spécifiées dans la spécification particulière.

5.9.3 Exigences, mesures et inspection finales

Les mesures finales après cet essai sont les mesures intermédiaires après les essais du sous-groupe 1B et avant le reste des essais du groupe 1.

Les condensateurs doivent être examinés visuellement et mesurés, ils doivent satisfaire aux exigences suivantes:

- aucun dommage visible ne doit être constaté. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées);
- la variation de capacité par rapport à la valeur mesurée dans le groupe 0 du Tableau K.3 ne doit pas dépasser 5 %, sauf pour les condensateurs en céramique pour lesquels elle ne doit pas dépasser 10 %;
- la valeur de tan δ ne doit pas dépasser la limite indiquée par la spécification particulière;
- la variation de résistance (le cas échéant) ne doit pas dépasser la limite spécifiée dans le Tableau 9.

Lorsque le préconditionnement est effectué, les mesures initiales pour référence doivent être réalisées après le préconditionnement.

5.10 Chocs

5.10.1 Généralités

La spécification particulière doit indiquer si l'essai de chocs ou de secousses s'applique.

Voir l'IEC 60384-1:2021, 7.6, avec les détails de 5.10.2 et 5.10.3.

5.10.2 Conditions d'essai

Les sévérités du Tableau 8 sont préférentielles.

Forme des impulsions: demi-sinusoïdale

Tableau 8 – Sévérités préférentielles d'essai de choc

Accélération de crête m/s^2	**Durée correspondante de l'impulsion** ms
500	11
1 000	6

La méthode de montage, la sévérité et le nombre de chocs le long de chaque axe doivent être spécifiés dans la spécification particulière.

5.10.3 Exigences, mesures et inspection finales

Les mesures finales après cet essai sont les mesures intermédiaires après les essais du sous-groupe 1B et avant le reste des essais du groupe 1.

Les condensateurs doivent être examinés visuellement et mesurés, ils doivent satisfaire aux exigences suivantes:

- aucun dommage visible ne doit être constaté. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées);
- la variation de capacité par rapport à la valeur mesurée dans le groupe 0 du Tableau K.3 ne doit pas dépasser 5 %, sauf pour les condensateurs en céramique pour lesquels elle ne doit pas dépasser 10 %;
- la valeur de tan δ ne doit pas dépasser la limite indiquée par la spécification particulière;
- la variation de résistance (le cas échéant) ne doit pas dépasser la limite spécifiée dans le Tableau 9.

Lorsque le préconditionnement est effectué, les mesures initiales pour référence doivent être réalisées après le préconditionnement.

5.11 Étanchéité des boîtiers

5.11.1 Généralités

Cet essai est uniquement applicable si la spécification particulière le prescrit.

Voir l'IEC 60384-1:2021, 7.9, avec les détails de 5.11.2 et 5.11.3.

5.11.2 Conditions d'essai

Les condensateurs doivent être soumis à l'essai Qc ou à l'essai Qd de l'IEC 60068-2-17, suivant le cas. Sauf indication contraire dans la spécification particulière, la méthode 1 doit être utilisée lorsque l'essai Qc est utilisé.

5.11.3 Exigences

Pendant ou après l'essai, selon le cas, aucune fuite ne doit être constatée.

5.12 Séquence climatique

5.12.1 Généralités

Lorsque, pour des condensateurs fixes à diélectrique en céramique de Classe 2, une mesure précise de la dérive de capacité est exigée, il convient d'effectuer un préconditionnement selon les conseils du fabricant (voir Annexe G).

Voir l'IEC 60384-1:2021, 8.2, avec les détails de 5.12.2 à 5.12.7.

5.12.2 Mesures initiales

Les mesures initiales pour la séquence climatique sont les mesures effectuées en 5.5.3, 5.9.3 ou 5.10.3, selon le cas.

5.12.3 Chaleur sèche

Voir l'IEC 60384-1:2021, 8.2.3, avec les détails suivants.

Aucune mesure n'est exigée à la température maximale de catégorie.

5.12.4 Chaleur humide, cyclique, essai Db, premier cycle

Voir l'IEC 60384-1:2021, 8.2.4.

5.12.5 Froid

Voir l'IEC 60384-1:2021, 8.2.5, avec les détails suivants.

Aucune mesure n'est exigée à la température minimale de catégorie.

5.12.6 Chaleur humide, cyclique, essai Db, cycles restants

Voir l'IEC 60384-1:2021, 8.2.7.

5.12.7 Exigences, mesures et inspection finales

Voir l'IEC 60384-1:2021, 8.2.8, avec les détails suivants.

Le rétablissement doit durer (24 ± 2) h dans les conditions atmosphériques normales pour les essais.

Après rétablissement, les condensateurs doivent faire l'objet d'un examen visuel, être mesurés et satisfaire aux exigences du Tableau 9.

Tableau 9 – Séquence climatique – Exigences

Inspection ou mesure	Méthode d'inspection ou de mesure	Exigences
Examen visuel	5.2	Aucun dommage visible. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées). Le marquage doit être lisible
Capacité	5.3.2	La valeur finale de la capacité ne doit pas s'écarter de plus de 5 %[a] de la valeur mesurée en 5.5.3, 5.9.3 ou 5.10.3, selon le cas
Tangente de l'angle de perte (condensateurs métallisés uniquement)	5.3.3	L'augmentation de tan δ par rapport à la valeur mesurée dans le groupe 0 ne doit pas dépasser: 0,008 pour $C_N \leq 1$ µF 0,005 pour $C_N > 1$ µF
Résistance (le cas échéant)	5.3.4	$\|\Delta R / R\| \leq 5$ %
Tension de tenue	5.3.1	Tension d'essai indiquée dans le Tableau 4. Aucun claquage permanent ni contournement n'est admis
Résistance d'isolement	5.3.5	Supérieure à 50 % des limites applicables indiquées dans le Tableau 5 ou le Tableau 6

[a] Pour les condensateurs en céramique, la différence de capacité ne doit pas dépasser 10 %.

5.13 Essai continu de chaleur humide (DHSS)

5.13.1 Généralités

Lorsque, pour des condensateurs fixes à diélectrique en céramique de Classe 2, une mesure précise de la dérive de capacité est exigée, il convient d'effectuer un préconditionnement selon les conseils du fabricant (voir Annexe G).

L'Annexe I décrit des niveaux de résistance à l'humidité, des essais et des exigences spécifiques pour des applications exigeant une grande stabilité dans des conditions de fonctionnement avec une forte humidité. Un échantillon soumis à essai pour satisfaire à l'un des niveaux de résistance de l'Annexe I satisfait aux exigences de la seconde moitié de l'échantillon décrit en 5.13.3 (essai continu de chaleur humide avec la tension appliquée), et les résultats d'essai sont valides pour les essais d'approbation conformément à 8.4, à l'Annexe F ou à l'Annexe K.

Voir l'IEC 60384-1:2021, 8.3, avec les détails de 5.13.2 à 5.13.4.

5.13.2 Mesures initiales

Des mesures initiales ont été réalisées dans le groupe 0 du Tableau 14 ou du Tableau 15.

Lorsque le préconditionnement est effectué, les mesures initiales doivent être réalisées après le préconditionnement.

5.13.3 Conditions d'essai

L'échantillon doit être divisé en deux parties de taille égale.

La première moitié de l'échantillon doit être soumise à essai sans tension appliquée avec les sévérités préférentielles suivantes:

- température: (40 ± 2) °C;
- humidité relative: (93 ± 3) %;
- durée: 21 jours ou 56 jours, selon la catégorie climatique du condensateur.

L'autre moitié de l'échantillon doit être soumise à essai avec la tension alternative assignée appliquée dans les conditions suivantes:

- température: (40 ± 2) °C;
- humidité relative: (93 ± 3) %;
- durée: 21 jours.

5.13.4 Exigences, mesures et inspection finales

Le rétablissement doit durer 1 h à 2 h dans les conditions atmosphériques normales pour les essais.

Après rétablissement, les condensateurs soumis à essai sans tension doivent faire l'objet d'un examen visuel, être mesurés et satisfaire aux exigences du Tableau 10.

Après rétablissement, les condensateurs soumis à essai sous tension doivent faire l'objet d'un examen visuel, être mesurés et satisfaire aux exigences du Tableau 11. Les exigences électriques du Tableau 11 sont identiques à celles du Tableau I.1.

Tableau 10 – Essai continu de chaleur humide – Exigences pour les échantillons soumis à essai sans tension appliquée

Inspection ou mesure	Méthode d'inspection ou de mesure	Exigences
Examen visuel	5.2	Aucun dommage visible. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées). Le marquage doit être lisible
Capacité	5.3.2	La valeur finale de la capacité ne doit pas s'écarter de plus de 5 %[a] de la valeur mesurée dans le groupe 0 du Tableau 16 ou du Tableau K.3, suivant le cas
Tangente de l'angle de perte (condensateurs métallisés uniquement)	5.3.3	L'augmentation de tan δ par rapport à la valeur mesurée dans le groupe 0 ne doit pas dépasser: 0,008 pour $C_N \leq 1$ µF 0,005 pour $C_N > 1$ µF
Résistance (le cas échéant)	5.3.4	$\lvert \Delta R / R \rvert \leq 5$ %
Tension de tenue	5.3.1	Tension d'essai conforme au Tableau 4. Aucun claquage permanent ni contournement n'est admis
Résistance d'isolement	5.3.5	Supérieure à 50 % des limites applicables indiquées dans le Tableau 5 ou le Tableau 6

[a] Pour les condensateurs en céramique, la différence de capacité ne doit pas dépasser 15 %.

Tableau 11 – Essai continu de chaleur humide – Exigences pour les échantillons soumis à essai sous tension

Mesure	Méthode de mesure	Exigences
Examen visuel	5.2	Aucun dommage visible. Lors d'un examen visuel après l'essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d'isolement spécifiées dans le Tableau 3 doivent être assurées). Le marquage doit être lisible
Capacité	5.3.2	Condensateurs métallisés: $\lvert \Delta C \rvert \leq 10\ \%$ Condensateurs en céramique: $\lvert \Delta C \rvert \leq 15\ \%$
Tangente de l'angle de perte (condensateurs métallisés uniquement)	5.3.3	L'augmentation de tan δ au-delà de la valeur mesurée dans le Groupe 0 ne doit pas dépasser: 0,024 pour $C_N \leq 1\ \mu F$ [a] 0,015 pour $C_N > 1\ \mu F$ [a]
Résistance (le cas échéant)	5.3.4	$\lvert \Delta R / R \rvert \leq 5\ \%$
Tension de tenue	5.3.1	Tension d'essai conforme au Tableau 4
Résistance d'isolement	5.3.5	Supérieure à 50 % des limites applicables indiquées dans le Tableau 5 ou le Tableau 6 ou au moins égale à 200 MΩ, selon la valeur qui est la plus élevée

La variation de la valeur de la capacité dépend de la technologie utilisée et, par exemple dans le cas de condensateurs en céramique, elle peut être réversible. Les exigences sont par conséquent différentes.

[a] Pour certaines applications, des valeurs plus faibles de l'augmentation de tan δ peuvent être exigées.

5.13.5 Récapitulatif de l'effectif d'échantillons pour les essais d'humidité

Le Tableau 12 présente les effectifs d'échantillons pour les essais d'humidité conformément à 5.13, à l'Annexe H et à l'Annexe I.

Tableau 12 – Effectifs d'échantillons pour les essais d'humidité

Groupe d'essais DHSS	Sans tension	U_R courant alternatif appliquée	U_R courant continu appliquée
5.13	6	6^b	
Annexe H, Tableau H.1	+ 0	+ 0	+ 6^a
Annexe I, Niveau (I), (II), (III)	+ 0	10	+ 6^a

NOTE Le signe + devant les nombres signifie un échantillon supplémentaire selon 5.13.

[a] Échantillon supplémentaire si les condensateurs sont également spécifiés pour U_R courant continu supérieure à U_R courant alternatif (efficace)

[b] Voir 5.13.1

5.14 Tension de choc

5.14.1 Généralités

Cet essai est à réaliser comme une séquence avec l'essai d'endurance décrit en 5.15.

5.14.2 Mesures initiales

Des mesures initiales ont été réalisées dans le groupe 0 du Tableau 17 ou du Tableau K.3.

Lorsque le préconditionnement est effectué, les mesures initiales doivent être réalisées après le préconditionnement.

5.14.3 Conditions d’essai

Chaque condensateur différent doit être soumis à un maximum de 24 chocs de même polarité. Le temps entre les impulsions ne doit pas être inférieur à 10 s. La valeur de crête de la tension de choc doit être comme indiqué dans le Tableau 1 et le Tableau 2.

Le temps de montée, $t_{\mathrm{r},}$ est défini comme $t_{\mathrm{r}} = (t_{90} - t_{30}) \times 1{,}67$. Le temps t_{r} est la durée du front T_1 définie dans l’IEC 60060-1:2010, 7.1.18.

Le temps de descente, t_{d}, est égal à la moitié de la valeur T_2 définie dans l’IEC 60060-1:2010, 7.1.22.

La forme d’onde est déterminée par les paramètres du circuit d’essai. Les détails sur le circuit d’essai sont donnés à l’Annexe A.

Avant l’utilisation, le fonctionnement du circuit doit être contrôlé en utilisant des valeurs C_{X} de 0,01 µF et de 0,1 µF et des valeurs pour les autres éléments de circuit données dans le Tableau A.1. Le temps de montée, t_{r} et le temps de descente t_{d} ne doivent pas s’écarter de plus de (0 + 50) % des valeurs données dans le Tableau A.2. Il convient que les condensateurs C_{X} utilisés pour ce contrôle ne soient pas des condensateurs en céramique à forte permittivité.

Si la forme d’onde issue du contrôle affiche une oscillation amortie, la valeur crête à crête de cette oscillation, U_{pp}, ne doit pas dépasser 10 % de la tension de crête du choc, U_{CR} représentée à la Figure 6.

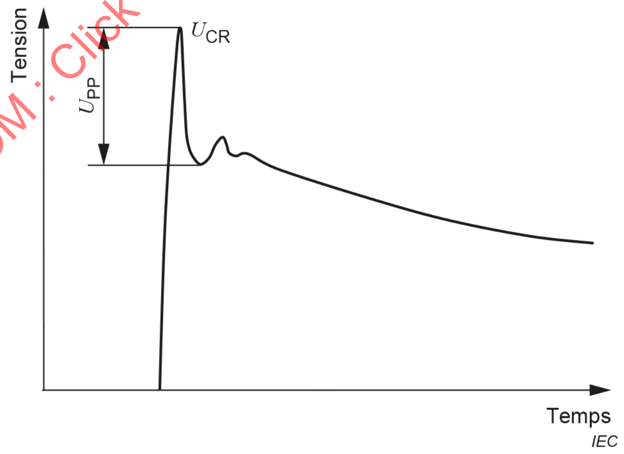


Figure 6 – Forme d’onde d’un choc

5.14.4 Exigences

Aucun claquage permanent ni contournement ne doit être constaté.

Si trois chocs successifs quelconques affichés sur l’oscilloscope présentent une forme d’onde indiquant qu’il n’y a pas eu de claquage autocicatrisant ni de contournement dans le condensateur, alors aucun autre choc ne doit être appliqué et le condensateur doit être considéré comme conforme.

Si les 24 impulsions ont été appliquées au condensateur et qu'au moins 3 d'entre elles ont une forme d'onde indiquant qu'aucun claquage autocicatrisant ni contournement ne s'est produit, alors le condensateur doit être considéré comme conforme, mais si moins de trois impulsions présentent la forme d'onde exigée, alors le condensateur doit être considéré comme non conforme.

5.15 Endurance

5.15.1 Généralités

Lorsque, pour des condensateurs fixes à diélectrique en céramique de Classe 2, une mesure précise de la dérive de capacité est exigée, il convient d'effectuer un préconditionnement selon les conseils du fabricant (voir Annexe G).

L'essai d'endurance doit commencer moins d'une semaine après la fin de l'essai de tension de choc. Voir l'IEC 60384-1:2021, 8.5, avec les détails de 5.15.2 à 5.15.9.

5.15.2 Conditions d'essai

Les condensateurs doivent être placés dans la chambre d'essai de telle manière que la distance entre chaque condensateur soit d'au moins 25 mm.

Toutefois, il existe une exception: quand la largeur ou le diamètre du condensateur est inférieur à 25 mm, la distance entre les condensateurs peut être réduite à la valeur de cette largeur ou de ce diamètre, à condition que ceci ne produise aucun réchauffement supplémentaire des condensateurs. En cas de doute, un espacement de 25 mm doit être utilisé.

Les condensateurs ne doivent pas être chauffés par rayonnement direct et la circulation d'air dans la chambre doit être appropriée pour empêcher que la température ne dépasse de ± 3 °C la température spécifiée, quel que soit l'endroit où les condensateurs sont placés.

Pour les condensateurs non autocicatrisants, un fusible de 1 A ou plus, si la valeur de la capacité en essai l'exige, doit être branché dans le circuit d'alimentation et ne doit pas fondre pendant l'essai.

Pour les condensateurs autorégénérateurs, un fusible ou tout autre dispositif de sensibilité appropriée peut être branché dans le circuit de chaque condensateur pour indiquer si une défaillance se produit.

5.15.3 Échantillonnage

Le cas échéant, l'échantillon pour l'essai d'endurance doit être divisé en deux ou trois parties en fonction des nombres indiqués dans le Tableau 15, le Tableau K.1, le Tableau 17 ou le Tableau K.3, de sorte que des essais séparés puissent être réalisés sur les condensateurs de classe X, les condensateurs de classe Y et les condensateurs de traversée.

Par exemple, pendant les essais sur des unités de condensateurs connectés en triangle (voir 3.1.9), 12 unités de condensateurs doivent être soumises à des essais conformément à 5.15.5 et 12 autres unités conformément à 5.15.6. Lors des essais d'un condensateur de traversée de classe Y (voir 3.1.8), 12 condensateurs doivent être soumis à essai conformément à 5.15.6 et six unités conformément à 5.15.7.

5.15.4 Mesures initiales

Les mesures initiales ont été réalisées en 5.14.2.

5.15.5 Endurance pour des condensateurs de classe X et des unités RC contenant des condensateurs de classe X

Pour les condensateurs à plusieurs sections, toutes les sections X doivent être soumises à des essais en parallèle, si nécessaire, en court-circuitant toutes les sections Y. Pour les condensateurs connectés en T (voir 3.1.9), l'essai doit être réalisé entre les bornes connectées normalement à la ligne et au neutre.

Les condensateurs et les unités RC, pour lesquelles aucune température assignée n'est donnée, doivent être soumis à un essai d'endurance de 1 000 h à la température maximale de catégorie à une tension de 1,25 U_R, sauf qu'une fois par heure la tension doit être augmentée jusqu'à la tension U_S efficace pendant 0,1 s, où $U_S = 1{,}5 \times U_R$ ou 1 000 V efficace, la plus grande des deux valeurs étant retenue. Chacune de ces tensions doit être appliquée à chaque condensateur individuellement par une résistance de 47 Ω, avec une tolérance de ± 5 %. Le circuit approprié est représenté à l'Annexe B.

La valeur de cette résistance est choisie de manière à simuler l'impédance à haute fréquence du réseau d'alimentation. Pour les condensateurs dont la capacité est supérieure à 10 µF, la puissance dissipée dans la résistance devient grande. Lorsque les valeurs de capacité augmentent, la puissance dissipée peut atteindre un niveau irréalisable. Dans ce genre de situation, les laboratoires d'essai de sécurité peuvent autoriser l'utilisation de valeurs de résistance correspondant à 5 % de la valeur de la réactance du condensateur d'essai, C_x.

Les unités RC, pour lesquelles une température assignée est donnée, doivent être montées de la façon spécifiée par le fabricant et l'étuve doit être stabilisée à la température assignée sans tension appliquée aux condensateurs. La tension doit alors être établie et le temps compté à partir de ce moment.

Après que la stabilité thermique due au chauffage interne de la résistance a été rétablie, la température du boîtier d'un des condensateurs doit être mesurée. Elle ne doit pas dépasser la température maximale de catégorie.

Il convient de concevoir le circuit d'essai de sorte que les tensions transitoires et les surintensités soient évitées pendant la commutation. Cela peut être obtenu en déchargeant le condensateur avant de commuter vers la nouvelle tension à condition que le temps total nécessaire pour atteindre U_S efficace et revenir ne dépasse pas 30 s.

5.15.6 Endurance pour des condensateurs de classe Y et des unités RC contenant des condensateurs de classe Y

Pour les condensateurs à plusieurs sections, toutes les sections Y doivent être soumises à des essais en parallèle, si nécessaire, en court-circuitant toutes les sections X. Pour les condensateurs connectés en T (voir 3.1.9), les bornes normalement connectées à la ligne et au neutre doivent être court-circuitées, et l'essai doit être effectué entre ces bornes et la borne normalement connectée à la terre.

Les condensateurs doivent être soumis à un essai d'endurance de 1 000 h à la température maximale de catégorie à une tension de 1,7 U_R, sauf qu'une fois par heure la tension doit être augmentée jusqu'à la tension U_S efficace pendant 0,1 s, où U_S = 1 000 V efficace. Chacune de ces tensions doit être appliquée à chaque condensateur individuellement par une résistance de 47 Ω avec une tolérance de ± 5 %. Le circuit d'essai est représenté à l'Annexe B.

Il convient de concevoir le circuit d'essai de sorte que les tensions transitoires et les surintensités soient évitées pendant la commutation. Cela peut être obtenu en déchargeant le condensateur avant de commuter vers la nouvelle tension à condition que le temps total nécessaire pour atteindre U_S efficace et revenir ne dépasse pas 30 s.

5.15.7 Endurance pour les condensateurs à sortie traversante

Outre les essais d’endurance des condensateurs selon 5.15.5 et 5.15.6, le courant admissible des condensateurs de traversée doit être soumis à essai. Tous les fils de traversée doivent être connectés en série et les condensateurs doivent être soumis à un essai d’endurance de 1 000 h avec un courant de 1,1 I_R traversant les fils de traversée. Pendant cet essai, aucune tension n’est appliquée au diélectrique du condensateur.

Les condensateurs doivent être montés de la façon spécifiée par le fabricant et l’étuve doit être stabilisée à la température assignée sans courant traversant les condensateurs. Le courant doit alors être établi et le temps compté à partir de ce moment.

Après rétablissement de la stabilité thermique, la température du boîtier d’un des condensateurs doit être mesurée. Elle ne doit pas dépasser la température maximale de catégorie.

5.15.8 Conditions d’essai – Essais tension/courant combinés

Pour certains types de condensateurs, tels que les condensateurs de traversée coaxiaux, il est possible sans difficulté d’appliquer simultanément la tension et le courant d’essai au condensateur. Si cela est indiqué dans la spécification particulière, un essai d’endurance combiné de 1 000 h peut être effectué à la place des essais de 5.15.5 (ou de 5.15.6) et de 5.15.7 en utilisant le nombre de spécimens appropriés pour l’essai de 5.15.5 (ou de 5.15.6) et 1,1 fois le courant assigné circulant dans les condensateurs de traversée.

La température du boîtier d’un des condensateurs doit être mesurée conformément à 5.15.7. Elle ne doit pas dépasser la température maximale de catégorie.

5.15.9 Exigences, mesures et inspection finales

Les condensateurs doivent faire l’objet d’un examen visuel et être mesurés dans l’ordre donné dans le Tableau 13.

Tableau 13 – Endurance – Exigences

Inspection ou mesure	**Méthode d’inspection ou de mesure**	**Exigences**
Examen visuel	5.2	Aucun dommage visible. Lors d’un examen visuel après l’essai, le revêtement du condensateur ne doit présenter aucune fissure exposant des parties actives internes ou dans des zones isolées définies (la ligne de fuite et la distance d’isolement spécifiées dans le Tableau 3 doivent être assurées).
Capacité	5.3.2	La valeur finale de la capacité ne doit pas s’écarter de plus de 10 % [a] de la valeur du groupe 0 du Tableau 15 ou du Tableau K.1 selon le cas
Tangente de l’angle de perte (condensateurs métallisés uniquement)	5.3.3	L’augmentation de tan δ par rapport à la valeur mesurée dans le groupe 0 ne doit pas dépasser: 0,008 pour $C_N \leq 1$ µF 0,005 pour $C_N > 1$ µF
Résistance (le cas échéant)	5.3.4	$\lvert \Delta R / R \rvert \leq 10$ %
Tension de tenue	5.3.1	Tension d’essai conforme au Tableau 4. Aucun claquage permanent ni contournement n’est admis
Résistance d’isolement	5.3.5	Supérieure à 50 % des limites applicables indiquées dans le Tableau 5 ou le Tableau 6

[a] Pour les condensateurs en céramique, la différence de capacité ne doit pas dépasser 20 %.

5.16 Charge et décharge

5.16.1 Généralités

Cet essai s’applique uniquement aux condensateurs métallisés, aux condensateurs en céramique et aux unités RC mettant en œuvre de tels condensateurs.

Voir l’IEC 60384-1:2021, 6.11, avec les détails de 5.16.2 à 5.16.4.

5.16.2 Mesures initiales

Des mesures initiales ont été réalisées dans le groupe 0 du Tableau 15 ou du Tableau K.1. De plus, sauf dans le cas des unités RC, tan δ doit être mesurée conformément à l’IEC 60384-1:2021, 6.4, avec les détails suivants:

C_N:	≤ 1 µF	C_N:	> 1 µF
Fréquence:	10 kHz	Fréquence:	1 kHz
Tension:	1 V eff. max.	Tension de crête:	≤ 3 % de la tension assignée

Lorsque le préconditionnement est effectué, les mesures initiales doivent être réalisées après le préconditionnement.

5.16.3 Conditions d’essai

Les condensateurs doivent être soumis à 10 000 cycles de charge et de décharge à une cadence d’environ une opération par seconde.

Chaque cycle doit être constitué d’une charge et d’une décharge du condensateur. Pour les condensateurs pour courant alternatif, la tension d’essai doit être égale à $\sqrt{2} \times U_R$ et pour les condensateurs en courant continu, la tension d’essai doit être U_R.

Chaque condensateur doit être chargé individuellement en appliquant la tension d’essai par une résistance dont la valeur est égale à:

$$R = \frac{220 \times 10^{-6}}{C_N} \ \Omega$$

ou la valeur exigée pour limiter le courant de charge à 1 A (ou à la valeur de courant plus élevée donnée dans la spécification particulière), la plus grande des valeurs de résistance étant retenue.

Chaque condensateur doit être déchargé individuellement à travers une résistance de valeur telle que la vitesse maximale de variation de tension ($\mathrm{d}U/\mathrm{d}t$) doit être d’environ 100 V/µs.

Pour les unités RC, s’il est impossible d’obtenir un régime de décharge de 100 V/µs, l’unité RC doit être déchargée par un court-circuit.

Le circuit est représenté à l’Annexe C.

Dans l’Annexe E (Circuits d’essai d’impulsions), d’autres possibilités de circuit d’essai sont données à titre d’information.