BS EN 60384-1:2016

BSI Standards Publication

Fixed capacitors for use in electronic equipment

Part 1: Generic specification

bsi.

National foreword

This British Standard is the UK implementation of EN 60384-1:2016. It is identical to IEC 60384-1:2016. It supersedes BS EN 60384-1:2009 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/40X, Capacitors and resistors for electronic equipment.

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

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

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EUROPEAN STANDARD

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English Version

Fixed capacitors for use in electronic equipment - Part 1: Generic specification (IEC 60384-1:2016)

Condensateurs fixes utilisés dans les équipements électroniques - Partie 1: Spécification générique (IEC 60384-1:2016)

Festkondensatoren zur Verwendung in Geräten der Elektronik - Teil 1: Fachgrundspezifikation (IEC 60384-1:2016)

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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 60384-1:2016 E

European foreword

The text of document 40/2420/FDIS, future edition 5 of IEC 60384-1, prepared by IEC/TC 40 "Capacitors and resistors for electronic equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60384-1:2016.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2017-03-30
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2019-09-30

This document supersedes EN 60384-1:2009.

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Endorsement notice

The text of the International Standard IEC 60384-1:2016 was approved by CENELEC as a European Standard without any modification.

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

IEC 60384-2	NOTE	Harmonized as EN 60384-2.
IEC 60384-3	NOTE	Harmonized as EN 60384-3.
IEC 60384-3-1	NOTE	Harmonized as EN 60384-3-1.
IEC 60384-26	NOTE	Harmonized as EN 60384-26.
IEC 60469:2013	NOTE	Harmonized as EN 60469:2013.
ISO 9000	NOTE	Harmonized as EN ISO 9000.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60027	series	Letter symbols to be used in electrical technology	EN 60027	series
IEC 60050	series	International Electrotechnical Vocabulary	-	series
IEC 60062	-	Marking codes for resistors and capacitors	EN 60062	-
IEC 60063	-	Preferred number series for resistors and capacitors	EN 60063	-
IEC 60068-1	2013	Environmental testing -- Part 1: General and guidance	EN 60068-1	2014
IEC 60068-2-1	2007	Environmental testing -- Part 2-1: Tests - Test A: Cold	EN 60068-2-1	2007
IEC 60068-2-2	2007	Environmental testing -- Part 2-2: Tests - Test B: Dry heat	EN 60068-2-2	2007
IEC 60068-2-6	2007	Environmental testing -- Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	2008
IEC 60068-2-13	1983	Basic environmental testing procedures - Part 2-13: Tests - Test M: Low air pressure	EN 60068-2-13	1999
IEC 60068-2-14	2009	Environmental testing -- Part 2-14: Tests - Test N: Change of temperature	EN 60068-2-14	2009
IEC 60068-2-17	1994	Basic environmental testing procedures - Part 2-17: Tests - Test Q: Sealing	EN 60068-2-17	1994
IEC 60068-2-20	2008	Environmental testing -- Part 2-20: Tests - Test T: Test methods for solderability and resistance to soldering heat of devices with leads	EN 60068-2-20	2008
IEC 60068-2-21	2006	Environmental testing -- Part 2-21: Tests - Test U: Robustness of terminations and integral mounting devices	EN 60068-2-21	2006
IEC 60068-2-27	2008	Environmental testing -- Part 2-27: Tests - Test Ea and guidance: Shock	EN 60068-2-27	2009
IEC 60068-2-30	2005	Environmental testing -- Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)	EN 60068-2-30	2005
IEC 60068-2-45 AMD 1	1993	Basic environmental testing procedures; part_2: tests; test_XA and guidance: immersion in cleaning solvents; amendment_1	-	-
IEC 60068-2-45	1980	Basic environmental testing procedures - Part 2-45: Tests - Test XA and guidance: Immersion in cleaning solvents	EN 60068-2-45	1992

IEC 60068-2-54	2006	Environmental testing - Part 2-54: Tests - Test Ta: Solderability testing of electronic components by the wetting balance method	EN 60068-2-54	2006
IEC 60068-2-58	2015	Environmental testing - Part 2-58: Tests - Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)	EN 60068-2-58	2015
IEC 60068-2-67	1995	Environmental testing -- Part 2: Tests - Test Cy: Damp heat, steady state, accelerated test primarily intended for components	EN 60068-2-67	1996
IEC 60068-2-69	2007	Environmental testing - Part 2: Tests - Test Te: Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method	EN 60068-2-69	2007
IEC 60068-2-78	2012	Environmental testing -- Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	2013
IEC 60068-2-82	2007	Environmental testing -- Part 2-82: Tests - Test XW1: Whisker test methods for electronic and electric components	EN 60068-2-82	2007
IEC 60294	-	Measurement of the dimensions of a cylindrical component with axial terminations	EN 60294	-
IEC 60617	-	Standard data element types with associated classification scheme for electric components -- Part 4: IEC reference collection for standard data element types and component classes		-
IEC 60695-11-5	2004	Fire hazard testing -- Part 11-5: Test flames - Needle-flame test method - Apparatus, confirmatory test arrangement and guidance	EN 60695-11-5	2005
IEC 60717	-	Method for the determination of the space required by capacitors and resistors with unidirectional terminations	EN 60717	-
IEC 61193-2	-	Quality assessment systems -- Part 2: Selection and use of sampling plans for inspection of electronic components and packages	EN 61193-2	-
IEC 61249-2-7	2002	Materials for printed boards and other interconnecting structures -- Part 2-7: Reinforced base materials, clad and unclad - Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad	EN 61249-2-7	2002
-	-		+ corrigendum Sep.	2005
ISO 3	-	Preferred numbers; Series of preferred numbers		-
ISO 80000-1	-	Quantities and units -- Part 1: General	EN ISO 80000-1	-

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

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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International Standard IEC 60384-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment

This fifth edition cancels and replaces the fourth edition published in 2008 and constitutes a technical revision, including minor revisions related to tables, figures and references.

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

- INTRODUCTION added;
- 4.41 Whisker growth test added;
- Annex Q completely restructured.

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

FDIS	Report on voting
40/2420/FDIS	40/2444/RVD

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

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

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

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

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

INTRODUCTION

The specification system for fixed capacitors for use in electronic equipment is structured in a hierarchical system consisting of the following specification types.

Generic specification

The generic specification covers all subjects mainly common to the family of fixed capacitors for use in electronic equipment, such as terminology, methods of measurement and tests. Where the individual subjects require the prescription conditions or parameters specific to the particular subfamily or type of fixed capacitor, such prescriptions are required to be given by one of the subordinate specifications.

For the scope of fixed capacitors, the numeric reference to the generic specification is IEC 60384-1.

Sectional specification

Sectional specifications cover all subjects additional to those given in the generic specification, which are specific to a defined sub-group of fixed capacitors. These subjects normally are preferred values for dimensions and characteristics, additional test methods and relevant prescriptions for test methods given in the generic specification, prescriptions for sampling and for the preparation of specimen, recommended test severities and preferred acceptance criteria. The sectional specification also outlines the structure and scope of the test schedules which are to be applied in all subordinate detail specifications.

For the scope of fixed capacitors, the numeric references to the sectional specifications reach from IEC 60384-2 for polyester film capacitors to currently IEC 60384-26 for aluminium electrolytic capacitors with conductive polymer solid electrolyte. The variety of sectional specifications may be adapted to the portfolio of different technologies of fixed capacitors.

Detail specification

Detail specifications give directly, or by making reference to other specifications, all information necessary to completely describe a given type and range of fixed capacitors, including prescriptions of all values for dimensions and characteristics. They also give all information required for the quality assessment of the covered type and range of fixed capacitors within a suitable quality assessment system, including prescriptions for all applied test severities and acceptance criteria, and the completed test schedules.

Detail specifications can be either specifications within the IEC system, another specification system linked to IEC, or specified by the manufacturer or user. For the scope of fixed capacitors, the numeric references to detail specifications are for example IEC 60384-3-101, if related to the sectional specification IEC 60384-3 and to the ancillary blank detail specification IEC 60384-3-1.

Blank detail specification

The hierarchical system of specifications is supplemented by one or more blank detail specifications to a sectional specification, which are used to ensure a uniform presentation of detail specifications. The blank detail specifications provide the specification writer with a template on the layout to be adopted and on the information to be given and with guidance for the preparation of detail specifications in line with the requirements of the superior generic or sectional specifications. Blank detail specifications are not considered as relevant specifications since they do not themselves describe any particular component.

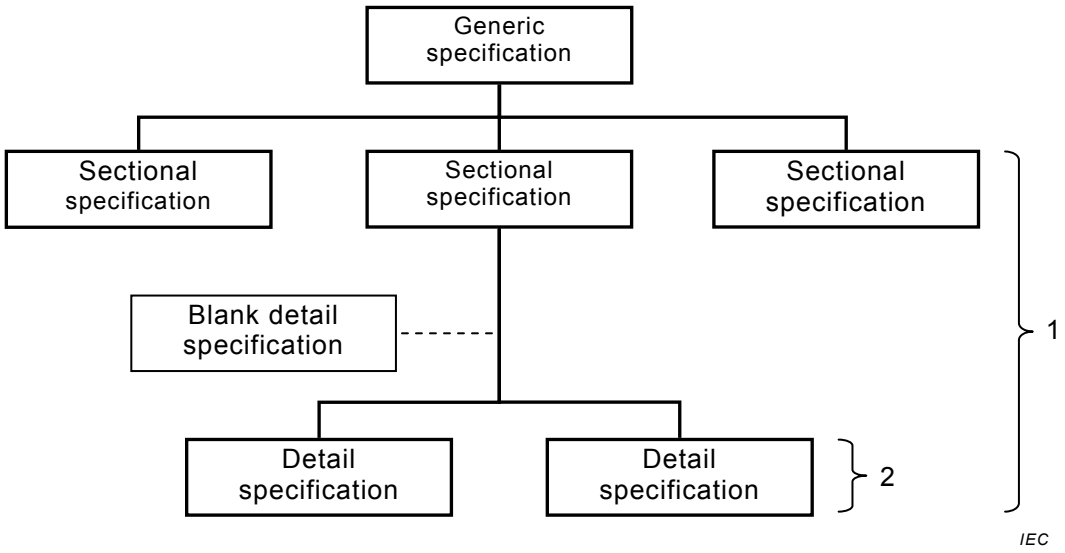
The presence of an established hierarchical specification system with blank detail specifications permits the preparation of detail specifications even outside of the relevant IEC technical committee.

For the scope of fixed capacitors, the numeric references to blank detail specifications are, for example, IEC 60384-3-1, if related to the sectional specification IEC 60384-3.

Relevant specification

In this system the term “relevant specification” addresses subordinate specifications containing specific requirements, where applicable.

Any generic or sectional specification may use abstract and universal references to subordinate specifications of either hierarchical level by use of the expression “relevant specification”.



Key

1 Indicates the range of “*Relevant specifications*” to the superior generic specification, where applicable.

2 Indicates the range of “*Relevant specifications*” to the superior sectional specification, where applicable.

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT –

Part 1: Generic specification

1 General

1.1 Scope

This part of IEC 60384 is a generic specification and is applicable to fixed capacitors for use in electronic equipment.

It establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications of electronic components for quality assessment or any other purpose.

1.2 Normative references

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

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050 (all parts), *International Electrotechnical Vocabulary*[1]

IEC 60062, *Marking codes for resistors and capacitors*

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

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

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Tests B: Dry heat*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-13:1983, *Environmental testing – Part 2-13: Tests – Test M: Low air pressure*

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

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

IEC 60068-2-20:2008, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

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

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1 www.electropedia.org

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-45:1980, *Environmental testing – Part 2-45: Tests – Test XA and guidance: Immersion in cleaning solvents*
IEC 60068-2-45:1980/AMD1:1993

IEC 60068-2-54:2006, *Environmental testing – Part 2-54: Tests – Test Ta: Solderability testing of electronic components by the wetting balance method*

IEC 60068-2-58:2015, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-67:1995, *Environmental testing – Part 2-67: Tests – Test Cy: Damp heat, steady state, accelerated test primarily intended for components*

IEC 60068-2-69:2007, *Environmental testing – Part 2-69: Tests – Test Te: Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60068-2-82:2007, *Environmental testing – Part 2-82: Tests – Test XW1: Whisker test methods for electronic and electric components*

IEC 60294, *Measurement of the dimensions of a cylindrical component with axial terminations*

IEC 60617, *Graphical symbols for diagrams*

IEC 60695-11-5:2004, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60717, *Method for the determination of the space required by capacitors and resistors with unidirectional terminations*

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

IEC 61249-2-7:2002, *Materials for printed boards and other interconnecting structures – Part 2-7: Reinforced base materials clad and unclad – Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

ISO 3, *Preferred numbers – Series of preferred numbers*

ISO 80000-1, *Quantities and units – Part 1: General*

2 Technical data

2.1 Symbols, units and abbreviated terms

2.1.1 General

Units, graphical symbols and letter symbols should, whenever possible, be taken from the following publications:

– IEC 60027 (series);
– IEC 60050 (series);
– IEC 60617;
– ISO 80000-1.

When further items are required, they should be derived in accordance with the principles of the publications listed above.

2.1.2 Letter symbols

C_N Nominal capacitance

DA Dielectric Absorption

du/dt Pulse handling capability

f_r Self-resonat frequency

I_{leak} leakage current

k_0 Maximum permissible pulse characteristics

L Self-inductance

R_{INS} Insulation resistance

T_A Lower category temperature

tan δ Tangent of loss angle

T_B Upper category temperature

T_C Category temperature

T_{op} Operating temperature

T_R Rated temperature

U_C Category voltage

U_{op} Operating voltage

U_R Rated voltage

U_{RS} Surge voltage

Z Impedance

α Temperature coefficient of capacitance

τ = $C_N \times R_{INS}$ Time constant

2.1.3 Abbreviations

CA Capability Approval

CB Certification Body

CQC Capability Qualifying Components

DMR Designated Management Representative

ESR Equivalent Series Resistance

IPA Isopropyl alcohol

PCP Process Control Plan

QA Qualifying Approval

SMD Surface Mount Device

TA Technology Approval

TADD Technology Approval Declaration Document

2.2 Terms and definitions

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

NOTE They have been listed in alphabetical order.

2.2.1
a.c. capacitor
capacitor designed essentially for application with alternating voltages

2.2.2
bipolar capacitor
<electrolytic capacitor> capacitor designed to withstand an alternating voltage and/or reversal of the applied direct voltage

2.2.3
category of passive flammability
category indicating the maximum burning time after a specified time of flame application

2.2.4
category temperature range
ambient temperature range for which the capacitor has been designed to operate continuously

Note 1 to entry: The temperature range is limited by the lower and upper category temperature (see 2.2.10 and 2.2.41).

2.2.5
category voltage
U_C
maximum voltage that can be applied continuously to a capacitor at its upper category temperature (2.2.41)

2.2.6
d.c. capacitor
capacitor designed essentially for application with direct voltage

Note 1 to entry: It may not be suitable for use on a.c. supplies.

2.2.7
family
<electronic components> group of components which predominantly displays a particular physical attribute and/or fulfils a defined function

2.2.8
grade
term to indicate an additional general characteristic concerning the intended application of the component

2.2.9
insulated capacitor
capacitor in which all terminations of a section may be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use

2.2.10
lower category temperature
minimum ambient temperature for which a capacitor has been designed to operate continuously

2.2.11
maximum storage temperature
maximum ambient temperature which the capacitor withstands in the non-operating condition without damage

2.2.12
maximum temperature of a capacitor
temperature at the hottest point of its external surface

Note 1 to entry: The terminations are considered to be part of the external surface.

2.2.13
minimum storage temperature
minimum ambient temperature which the capacitor withstands in the non-operating condition without damage

2.2.14
minimum temperature of a capacitor
temperature at the coldest point of the external surface

Note 1 to entry: The terminations are considered to be part of the external surface.

2.2.15
nominal capacitance
C_N
designated capacitance value, usually indicated on the capacitor

2.2.16
passive flammability
ability of a capacitor to burn with a flame as a consequence of the application of an external source of heat

2.2.17
polar capacitor
<electrolytic capacitor> capacitor intended for use with a unidirectional voltage connected according to the polarity indication

2.2.18
pulse capacitor
capacitor for use with pulses of current or voltage

Note 1 to entry: The definitions of IEC 60469 apply.

2.2.19
pulse equivalent circuit of a capacitor
equivalent circuit consisting of an ideal capacitor in series with its residual inductance and the equivalent series resistance (ESR)

Note 1 to entry: For pulse operation the equivalent series resistance will be similar to, but not identical with, the ESR measured with a sinusoidal voltage. The pulse ESR depends on the series of harmonics in the pulse and the variation of the losses with frequency.

2.2.20
rated a.c. load
maximum sinusoidal a.c. load which may be applied continuously to the terminations of a capacitor at any temperature between the lower category temperature (2.2.10) and the rated temperature (2.2.24)

2.2.21
rated pulse load
maximum pulse load which may be applied at a certain pulse repetition frequency to the terminations of a capacitor at any temperature between the lower category temperature (2.2.10) and the rated temperature (2.2.24)

2.2.22
rated ripple current
r.m.s. value of the maximum allowable alternating current of a specified frequency, at which the capacitor can be operated continuously at a specified temperature

Note 1 to entry: As the ripple current will generate a ripple voltage across the capacitor, the sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor should not exceed the rated voltage or temperature derated voltage, as applicable.

2.2.23
rated ripple voltage
r.m.s. value of the maximum allowable alternating voltage at a specified frequency superimposed on the d.c. voltage at which the capacitor may be operated continuously at a specified temperature

Note 1 to entry: The sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor should not exceed the rated voltage or temperature derated voltage, as applicable.

2.2.24
rated temperature
maximum ambient temperature at which the rated voltage may be continuously applied

2.2.25
rated voltage
U_R

2.2.25.1
rated d.c. voltage
maximum d.c. voltage which may be applied continuously to a capacitor at the rated temperature (2.2.24)

Note 1 to entry: The maximum d.c. voltage is the sum of the d.c. voltage and peak a.c. voltage or peak pulse voltage applied to the capacitor.

2.2.25.2
rated a.c. voltage
maximum r.m.s. alternating voltage which may be applied continuously to a capacitor at the rated temperature (2.2.24) and at a given frequency

2.2.25.3
rated pulse voltage
peak value of the pulse voltage within a given pulse wave form which may be applied continuously to a capacitor at the rated temperature (2.2.24)

2.2.26
reverse voltage
<polar capacitor> voltage applied to the capacitor terminations in the reverse polarity direction

Note 1 to entry: Reverse voltage applies to polar capacitors only.

2.2.27
self-healing
process by which the electrical properties of the capacitor, after a local breakdown of the dielectric, are rapidly and essentially restored to the values before the breakdown

2.2.28
style
subdivision of a type (2.2.39), generally based on dimensional factors, which may include several variants, generally of a mechanical order

2.2.29
subfamily
<electronic components> group of components within a family (2.2.7) manufactured by similar technological methods

2.2.30
surface mount capacitor
fixed capacitor whose small dimensions and nature or shape of terminations make it suitable for use in hybrid circuits and on printed boards

2.2.31
surge voltage ratio
quotient of the maximum instantaneous voltage which can be applied to the terminations of the capacitor for a specified time at any temperature within the category temperature range (2.2.4) and the rated voltage (2.2.25) or the temperature derated voltage (2.2.36), as appropriate

2.2.32
tangent of loss angle
tan δ
power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage at a specified frequency

2.2.33
temperature characteristics of capacitance
maximum variation of capacitance produced over a given temperature range within the category temperature range (2.2.4)

Note 1 to entry: The term characterizing this property applies mainly to capacitors of which the variations of capacitance as a function of temperature, linear or non-linear, cannot be expressed with precision and certainty.

Note 2 to entry: This characteristic is normally expressed as a percentage of the capacitance related to a reference temperature of 20 °C.

2.2.34
temperature coefficient of capacitance
α
rate of change of capacitance with temperature measured over a specified range of temperature

Note 1 to entry: The term characterizing this property applies to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

Note 2 to entry: This coefficient is normally expressed in parts per million per Kelvin (10^{-6}/K).

2.2.35
temperature cyclic drift of capacitance
maximum irreversible variation of capacitance observed at room temperature during or after the completion of a number of specified temperature cycles

Note 1 to entry: The term characterizing this property applies to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

Note 2 to entry: This drift is normally expressed as a percentage of the capacitance related to a reference temperature, usually 20 °C.

2.2.36
temperature derated voltage
maximum voltage that may be applied continuously to a capacitor, when it is at any temperature between the rated temperature (2.2.24) and the upper category temperature (2.2.41)

Note 1 to entry: Refer to 2.3.6.

2.2.37
temperature rise
temperature rise of the capacitor relative to the ambient temperature resulting from the losses in the capacitor due to operation under a.c., pulse or charge/discharge conditions

2.2.38
time constant
τ
product of the insulation resistance and the capacitance

Note 1 to entry: The time constant is normally expressed in seconds.

2.2.39
type
group of components having similar design features and manufacturing techniques, enabling them to be considered together, either for qualification approval or for quality conformance inspection

Note 1 to entry: These components are generally covered by a single detail specification.

Note 2 to entry: Components described in several detail specifications, may, in some cases, be considered as belonging to the same type.

2.2.40
uninsulated capacitor
capacitor in which one or more of the terminations of a section cannot be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use

2.2.41
upper category temperature
maximum ambient temperature for which a capacitor has been designed to operate continuously

2.2.42
visible damage
visible damage which reduces the usability of the capacitor for its intended purpose

2.3 Preferred values and additional technical requirements

2.3.1 General

Each sectional specification shall prescribe the preferred values appropriate to the subfamily; for nominal capacitance, see also 2.3.2.

2.3.2 Preferred values of nominal capacitance

The preferred values of nominal capacitance shall be taken from the series specified in IEC 60063.

2.3.3 Preferred values of rated voltage

The preferred values of the rated voltage are the values of the R10 series of ISO 3: 1,0 – 1,25 – 1,6 – 2,0 – 2,5 – 3,15 – 4,0 – 5,0 – 6,3 – 8,0 and their decimal multiples ($\times 10^n$, n: integer).

2.3.4 Rated a.c. load

The rated a.c. load may be expressed:

a) at low frequencies as a rated a.c. voltage;

b) at high frequencies as a rated a.c. current;

c) at intermediate frequencies as a rated reactive power (var).

This is shown in Figure 1.

For a particular type of capacitor, it may be necessary to specify one or more of the above characteristics.

Capacitors within the scope of this standard are normally less than 500 var at 50 Hz to 60 Hz. Low frequencies may be 50 Hz to 60 Hz, 100 Hz to 120 Hz, or 400 Hz. Voltages may be up to 600 V r.m.s. at 50 Hz to 60 Hz. However, capacitors for filters, transmitter or converter circuits

may be required to operate under power over a wide range of frequencies and up to 10 kvar at the higher frequencies with voltages up to 1 000 V r.m.s.

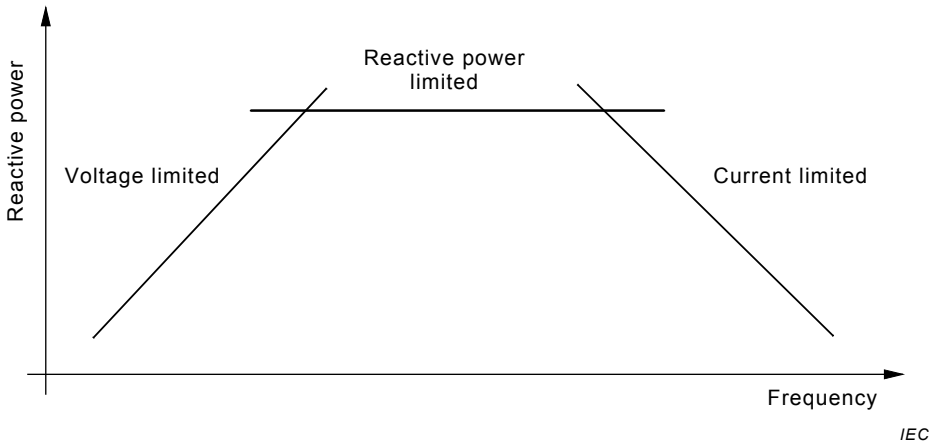


Figure 1 – Reactive power against frequency

2.3.5 Rated pulse load

The rated pulse load may be expressed as a) and b) and any of the remaining items:

a) peak current per μF or du/dt (V/μs);
b) relative duration of charge and discharge periods;
c) current;
d) peak voltage;
e) peak reverse voltage;
f) pulse repetition frequency;
g) maximum active power.

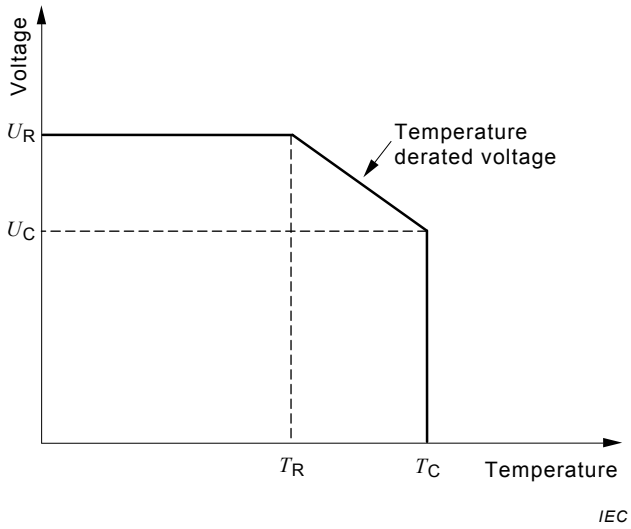
These parameters are fixed for periodic pulses.

In the case of intermittent pulses, the duty cycle should be specified. In the case of random pulses, the total number expected over a given time period should be stated.

The r.m.s. pulse current should be calculated in accordance with IEC 60469:2013, 3.2.17.5. In the case of intermittent or random pulses, the time interval should be chosen to correspond to the maximum temperature rise.

2.3.6 Temperature derated voltage

Information on the voltage/temperature dependence at temperatures between the rated temperature and the upper category temperature should, if applicable, be given in the relevant specification (see Figure 2).



Key

U_R is the rated voltage

U_C is the category voltage

T_R is the rated temperature

T_C is the category temperature

Figure 2 – Relation between category temperature range and applied voltage

2.4 Marking

2.4.1 General

The sectional specification shall indicate the identification criteria and other information to be shown on the capacitor and/or packaging.

The order of priority for marking small capacitors shall be specified.

2.4.2 Coding

When coding is used for capacitance value, tolerance or date of manufacture, the method shall be selected from those given in IEC 60062.

3 Quality assessment procedures

See Annex Q.

4 Tests and measurement procedures

4.1 General

The sectional and/or blank detail specification shall indicate the tests to be made, which measurements are to be made before and after each test or subgroup of tests, and the sequence in which they shall be made. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If national specifications within any quality assessment system include methods other than those specified in the above specifications, they shall be fully described.

Limits given in all specifications are absolute limits. The principle to take measurement uncertainty into account shall be applied.

4.2 Standard atmospheric conditions

4.2.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests and measurements shall be carried out under standard atmospheric conditions for testing as given in IEC 60068-1:2013, 4.3:

– temperature: 15 °C to 35 °C;
– relative humidity: 25 % to 75 %;
– air pressure: 86 kPa to 106 kPa.

Before the measurements are made, the capacitor shall be stored at the measuring temperature for a time sufficient to allow the entire capacitor to reach this temperature. The period as prescribed for recovery at the end of a test is normally sufficient for this purpose.

When measurements are made at a temperature other than the specified temperature, the results shall, where necessary, be corrected to the specified temperature. The ambient temperature during the measurements shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (as given in 4.2.3) and such other conditions as are prescribed in this standard.

When tests are conducted in a sequence, the final measurements of one test may be taken as the initial measurements for the succeeding test.

During measurements the capacitor shall not be exposed to draughts, direct sunlight or other influences likely to cause error.

4.2.2 Recovery conditions

Unless otherwise specified recovery shall take place under the standard atmospheric conditions for testing (4.2.1).

If recovery under closely controlled conditions is necessary, the controlled recovery conditions of IEC 60068-1:2013, 4.4.2, shall be used.

Unless otherwise specified in the relevant specification, a duration of 1 h to 2 h shall be used.

The definition of recovery is as given in IEC 60068-1:2013, 3.4, being further restricted for capacitors as follows:

When a recovery period is specified as, for example, 1 h to 2 h, this means that measurement (or other subsequent action) on a batch of capacitors may start after 1 h and shall be completed before 2 h from the beginning of the recovery period.

The preferred method of specifying a recovery period is in the form "x h to y h".

4.2.3 Referee conditions

For referee purposes, one of the standard atmospheric conditions for referee tests taken from IEC 60068-1:2013, 4.2, as given in Table 1 below, shall be selected.

Table 1 – Referee conditions

Temperature °C	Relative humidity %	Air pressure kPa
20 ± 1	63 to 67	86 to 106
23 ± 1	48 to 52	86 to 106
25 ± 1	48 to 52	86 to 106
27 ± 1	63 to 67	86 to 106

4.2.4 Reference conditions

For reference purposes, the standard atmospheric conditions for reference given in IEC 60068-1:2013, 4.1, apply:

– temperature: 20 °C;

– air pressure: 101,3 kPa.

4.3 Drying

Unless otherwise specified in the relevant specification, the capacitor shall be conditioned for 96 h ± 4 h by heating in a circulating air oven at a temperature of 55 °C ± 2 °C and a relative humidity not exceeding 20 %.

The capacitor shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

4.4 Visual examination and check of dimensions

4.4.1 Visual examination

The condition, workmanship and finish shall be satisfactory, as checked by visual examination (see 2.2.42).

Marking shall be legible, as checked by visual examination and shall conform with the requirements of the detail specification.

4.4.2 Dimensions (gauging)

The dimensions indicated in the detail specification as being suitable for gauging shall be checked, and shall comply with the values prescribed in the detail specification.

When applicable, measurements shall be made in accordance with IEC 60294 or IEC 60717.

4.4.3 Dimensions (detail)

All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

4.5 Insulation resistance

4.5.1 Preconditioning

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

4.5.2 Measuring conditions

Unless otherwise specified in the relevant specification, the insulation resistance shall be measured at the voltage specified in Table 2.

The insulation resistance shall be measured after the voltage has been applied for 60 s ± 5 s, unless otherwise prescribed in the detail specification.

Table 2 – Measurement of insulation resistance

Voltage rating of capacitor V	Measuring voltage V
U_R or U_c <10	U_R or U_c ± 10 %
10 ≤ U_R or U_c <100	10 ± 1[a]
100 ≤ U_R or U_c <500	100 ± 15
500 ≤ U_R or U_c	500 ± 50

[a] When it can be demonstrated that the voltage has no influence on the measuring result, or that a known relationship exists, measurements can be performed at voltages up to the rated or category voltage. In case of dispute, 10 V shall be used, unless otherwise specified in the sectional specification.

U_R is the rated voltage for use in defining the measuring voltage to be used under standard atmospheric conditions for testing.

U_C is the category voltage for use in defining the measuring voltage to be used at the upper category temperature.

4.5.3 Test points

The insulation resistance shall be measured between the measuring points defined in Table 3, specified in the relevant specification.

Test A, between terminations, applies to all capacitors, whether insulated or not.

Test B, internal insulation, applies to insulated capacitors in uninsulated metal cases and to insulated and uninsulated multiple section capacitors.

Test C, external insulation, applies to insulated capacitors in non-metallic cases or in insulated metal cases. For this test, the measuring voltage shall be applied using one of the three following methods as specified in the relevant specification:

4.5.4 Test methods

4.5.4.1 Foil method

A metal foil shall be closely wrapped around the body of the capacitor.

For capacitors with axial terminations this foil shall extend beyond each end by not less than 5 mm, provided that a minimum distance of 1 mm can be maintained between the foil and the terminations. If this minimum distance cannot be maintained, the extension of the foil shall be reduced by as much as is necessary to establish the distance of 1 mm.

For capacitors with unidirectional terminations, a minimum distance of 1 mm shall be maintained between the edge of the foil and each termination.

4.5.4.2 Method for capacitors with mounting devices

The capacitor shall be mounted in its normal manner on a metal plate, which extends at least 12,7 mm in all directions beyond the mounting face of the capacitor.

4.5.4.3 V-block method

The capacitor shall be clamped in the trough of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block.

The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned in accordance with the following:

a) for cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block;
b) for rectangular capacitors: the capacitor shall be positioned in the block so that the termination nearest the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors having axial terminations any out-of-centre positioning of the terminations at their emergence from the capacitor body shall be ignored.

4.5.5 Temperature compensation

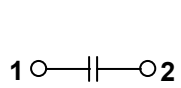
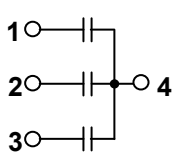
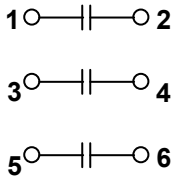
When prescribed in the detail specification, the temperature at which the measurement is made shall be noted. If this temperature differs from 20 °C, a correction shall be made to the measured value by multiplying the value by the appropriate correction factor prescribed in the sectional specification.

4.5.6 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the measuring points and the measuring voltage corresponding to each of these test points;
b) the method of applying the voltage (one of the methods described in 4.5.4);
c) time of electrification if other than 1 min;
d) any special precautions to be taken during measurements;
e) any correction factors required for measurement over the range of temperatures covered by the standard atmospheric conditions for testing;
f) the temperature of measurement if other than the standard atmospheric conditions for testing;
g) the minimum value of insulation resistance for the various measuring points (see Table 3).

Table 3 – Measuring points

Test	Applicable to:	1: Single-section capacitors e.g.  	2: Multiple-section capacitors having common termination for all sections **e.g.**  	3: Multiple-section capacitors having no common termination e.g. 
A. Between terminations[a]	All capacitors	1a: Between terminations (1–2)	2a: Between each of the terminations and the common termination (1-4, 2-4, 3-4)	3a: Between terminations of each section (1-2, 3-4, 5-6)
B. Internal insulation	Insulated single- and multiple-section capacitors in uninsulated metal cases (1b, 2b, 3b)	1b: Between terminations connected together and the case [(1 to 2)- case]	2b: Between all terminations connected together and the case [(1 to 4)- case]	3b: Between all terminations connected together and the case [(1 to 6)- case]
	Insulated and uninsulated multiple-section capacitors (2c and 3c)		2c: Between the non-common termination of each section and all the other terminations connected together e.g. [2-(1, 3, 4)]	3c: Between the terminations of separate sections, the two terminations of each section being connected together e.g.[(1 to 2)-(3 to 6)]
C. External insulation	Insulated capacitors in non-metallic cases or in insulated metal cases	1c: Between the two terminations connected together and, as appropriate, the metal foil, the metal plate or the metal V-block [(1 to 2)-metal jig	2d: [(1 to 4)-metal jig]	3d: [(1 to 6)-metal jig]
			Between all terminations connected together and, as appropriate: the metal foil, the metal plate or the metal V-block	

[a] Where a capacitor has more than two terminations, the measuring points are the two terminations which are insulated from one another by the capacitor's element dielectric. For example, for a coaxial lead-through capacitor, the measuring points should be one of the terminations connected to the central conductor and the coaxial metal case or mounting face.

4.6 Voltage proof

4.6.1 General

The test prescribed below is a d.c. test. When an a.c. test is applied, the test circuit shall be prescribed in the relevant specification.

4.6.2 Test circuit (for the test between terminations)

The test circuit elements shall be selected in such a way as to ensure that the conditions relating to the charging and discharging currents and the time constant for charging, prescribed in the relevant specification, are maintained.

Figure 3 specifies the characteristics of a suitable test circuit.

The resistance of the voltmeter shall be not less than 10 000 Ω/V.

The resistor R_1 includes the internal resistance of the voltage source.

The resistors R_1 and R_2 shall have a value sufficient to limit the charging and discharging current to the value prescribed in the relevant specification.

The capacitance of capacitor C_1 shall be not less than 10 times the capacitance of the capacitor under test.

If applicable, the time constant $R_1 \times (C_X + C_1)$ shall be less than, or equal to, the value prescribed in the relevant specification.

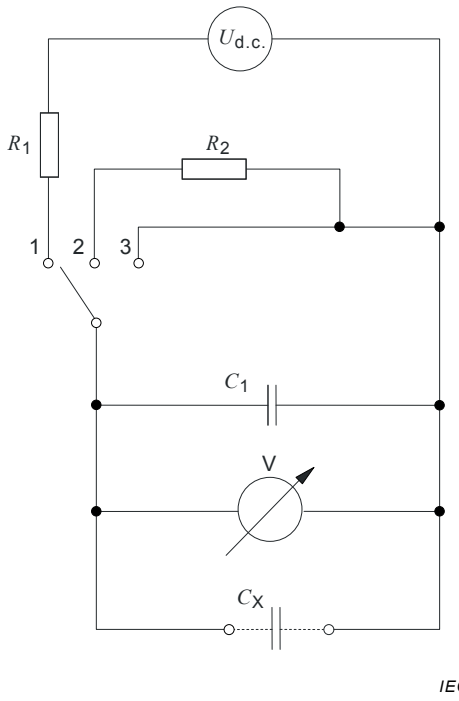


Figure 3 – Voltage-proof test circuit

The capacitor C_1 may be omitted for the testing of certain types of capacitors. This should be stated in the sectional specification.

4.6.3 Test

4.6.3.1 General

Depending on the case, the test comprises one or more parts in accordance with Table 3 and the requirements of the relevant specification.

Repeated application of the voltage proof test may cause permanent damage to the capacitor and should be avoided as far as possible.

4.6.3.2 Test A – Between terminations

4.6.3.2.1 Test points

The test voltage is applied to 1a, 2a, 3a of Table 3 in accordance with the requirements of the relevant specification.

4.6.3.2.2 Procedure

With the switch in position 2, connect the two terminals in Figure 3 to a variable d.c. supply of sufficient power adjusted to the required test voltage.

Connect the capacitor to be tested (C_X) to the test circuit as indicated in Figure 3.

Move the switch to position 1 so as to charge capacitors C_1 and C_X via R_1.

The switch remains in this position for the time specified after the test voltage has been reached.

Discharge the capacitors C_1 and C_X through R_2 by moving the switch to position 2. As soon as the voltmeter reading has fallen to zero, short-circuit the capacitors by moving the switch to position 3 and disconnect the capacitor C_X.

4.6.3.3 Test B – Internal insulation

4.6.3.3.1 Test points

The test voltage is applied to 1b, 2b, 2c, 3b, 3c of Table 3 in accordance with the requirements of the relevant specification.

4.6.3.3.2 Procedure

The specified test voltage is applied instantaneously via the internal resistance of the power supply for the time specified in the relevant specification. For point 2c use the test circuit and the procedure indicated for the test between terminations (4.6.2 and 4.6.3.2).

4.6.3.4 Test C – External insulation (applicable only to insulated capacitors in a non-metallic case or in an insulated metal case)

4.6.3.4.1 Test points

The test voltage is applied to 1c, 2d or 3d, using one of the three following methods for the application of the voltage in accordance with the requirements of the relevant specification.

4.6.3.4.2 Foil method

A metal foil shall be closely wrapped around the body of the capacitor.

For capacitors with axial terminations this foil shall extend beyond each end by not less than 5 mm, provided that a minimum distance of 1 mm/kV can be maintained between the foil and the terminations. If this minimum cannot be maintained, the extension of the foil shall be reduced by as much as is necessary to establish the distance of 1 mm/kV of test voltage.

For capacitors with unidirectional terminations, a minimum distance of 1 mm/kV shall be maintained between the edge of the foil and each termination.

In no case shall the distance between the foil and the terminations be less than 1 mm.

4.6.3.4.3 Method for capacitors with mounting devices

The capacitor shall be mounted in its normal manner on a metal plate which extends by not less than 12,7 mm in all directions beyond the mounting face of the capacitor.

4.6.3.4.4 V-block method

The capacitor shall be clamped in the trough of a 90° metallic V-block of such a size that the capacitor body does not extend beyond the extremities of the block.

The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned as follows:

a) for cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block;
b) for rectangular capacitors: the capacitor shall be positioned in the block so that the termination nearest the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors having axial terminations any out-of-centre positioning of the termination at its emergence from the capacitor body shall be ignored.

4.6.3.4.5 Procedure

The specified test voltage is applied instantaneously through the internal resistance of the power source for the time specified in the relevant specification.

4.6.4 Requirements

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

4.6.5 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the test points (see Table 3) and the test voltage corresponding to each of these points;
b) for the external insulation test (test C), the method of applying the test voltage (one of the methods described in 4.6.3.4);
c) the time for which the voltage is applied;
d) the maximum charging and discharging currents;
e) when applicable, the maximum value of the time constant for charging ($R_1 \times (C_1 + C_X)$).

4.7 Capacitance

4.7.1 Measuring frequency and measuring voltage

The capacitance shall be measured at one of the following frequencies, unless otherwise prescribed in the relevant specification:

– electrolytic capacitors:		100 Hz to 120 Hz
– other capacitors:	$C_N \leq 1$ nF:	100 kHz, 1 MHz or 10 MHz (1 MHz shall be reference)
	1 nF $< C_N \leq$ 10 μF:	1 kHz or 10 kHz (1 kHz shall be reference)
	$C_N >$ 10 μF:	50 Hz (60 Hz) or 100 Hz (120 Hz)

The tolerance on all frequencies for measuring purposes shall not exceed ±20 %.

The measuring voltage shall not exceed 3 % of U_R or 5 V, whichever is the smaller, unless otherwise prescribed in the relevant specification.

4.7.2 Measuring equipment

The accuracy of the measuring equipment shall be such that the error does not exceed:

a) for absolute capacitance measurements: 10 % of the capacitance tolerance or 2 % absolute, whichever is the smaller;
b) for measurement of variation of capacitance: 10 % of the specified maximum change of capacitance.

In neither case a) nor case b) need the accuracy be better than the minimum absolute measurement error (for example 0,5 pF) prescribed in the relevant specification.

4.7.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the measurement temperature if other than the standard atmospheric conditions for testing;
b) the frequencies for measurement and the capacitance range over which they apply, if different from those specified in 4.7.1;
c) the absolute measurement error, when applicable (for example 0,5 pF);
d) measuring voltage if different from the one specified in 4.7.1;
e) the applied polarizing voltage, when applicable.

4.8 Tangent of loss angle and equivalent series resistance (ESR)

4.8.1 Tangent of loss angle

4.8.1.1 Measuring frequency

The tangent of loss angle shall be measured under the same conditions as those given for the measurement of capacitance at one or more frequencies taken from the list in 4.7.1, as prescribed in the relevant specification.

4.8.1.2 Measuring accuracy

Unless otherwise specified in the sectional specification, the measuring method shall be such that the error does not exceed 10 % of the specified value or 0,000 3, whichever is the greater.

4.8.2 Equivalent series resistance (ESR)

4.8.2.1 Measuring frequency

The ESR shall be measured at one of the following frequencies, unless otherwise prescribed in the relevant specification:

50 Hz, 60 Hz, 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz and 10 MHz.

4.8.2.2 Measuring accuracy

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement, unless otherwise specified in the relevant specification.

4.8.2.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe

a) the frequency of measurement;
b) the absolute error measurement;
c) the measuring voltage, if different from that specified in 4.7.1;
d) the applied polarizing voltage, where applicable;
e) the temperature at which measurements shall be made, if other than the standard atmospheric conditions for testing.

4.9 Leakage current

4.9.1 Preconditioning

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

4.9.2 Test method

The leakage current shall be measured, unless otherwise prescribed in the relevant specification, using the direct voltage (U_R or U_C) appropriate to the test temperature, after a maximum electrification period of 5 min. The full 5 min electrification need not be applied if the specified leakage current limit is reached in a shorter time.

4.9.3 Power source

For the object of test, a steady source of power such as a regulated power supply shall be used.

4.9.4 Measuring accuracy

The measurement error shall not exceed ±5 % or 0,1 μA, whichever is the greater.

4.9.5 Test circuit

When prescribed in the relevant specification, a 1 000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current.

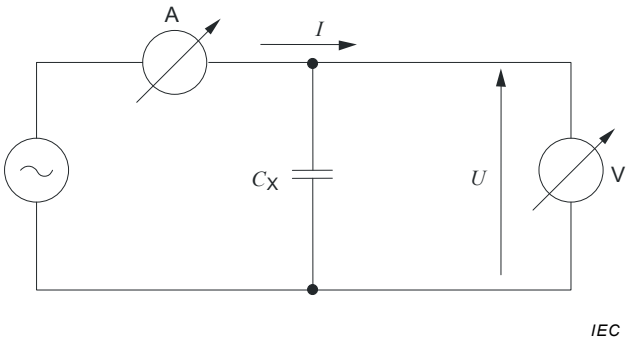
4.9.6 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the leakage current limit at a reference temperature of 20 °C, and at other specified temperatures;
b) when necessary, the correction factor, if the measurements are made at a temperature other than 20 °C, but within the range of temperatures covered by the standard atmospheric conditions for testing;
c) the electrification time, if different from 5 min;
d) whether or not a 1 000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current as defined in 4.9.5.

4.10 Impedance

Impedance shall be measured by the voltmeter-ammeter method according to the circuit of Figure 4, or equivalent.



Key

C_X	capacitance of specimen
U	measuring voltage
I	measuring current
A	ammeter
V	voltmeter

Figure 4 – Schematic diagram of the impedance measuring circuit

The impedance Z_X of the capacitor C_X is given by $Z_X = \frac{U}{I}$.

The frequency of the measuring voltage shall, preferably, be chosen from the following values:

50 Hz, 60 Hz, 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz and 10 MHz.

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement, unless otherwise specified in the relevant specification.

At frequencies above 120 Hz, precautions are necessary to avoid errors arising from stray currents. The current flowing through the capacitor should be limited so that the measuring result is not significantly affected by the rise of the temperature of the capacitor.

The relevant specification shall prescribe:

a) the frequency of measurement;

b) the temperature(s) at which measurements shall be made;

c) the limits of impedance, or ratio of impedances measured at different temperatures.

4.11 Self-resonant frequency and inductance

4.11.1 Self-resonant frequency (f_r)

4.11.1.1 General

For this measurement three methods are described. The first method is for general application; the other methods may be particularly suitable for measuring certain types of capacitors having low capacitance.

The accuracy of the measuring equipment shall be such that the error does not exceed 10 % of the requirement, unless otherwise specified in the relevant specification.

4.11.1.2 Method 1

Using the impedance measuring method of 4.10 and a variable frequency source, the lowest frequency shall be determined at which the impedance passes through a minimum. This is the self-resonant frequency.

When it is difficult to determine precisely the frequency at which the impedance is at a minimum, then use may be made of a phase-meter to compare the phase of the voltage across the capacitor with the phase of the voltage across a low-inductance resistor connected in series with the capacitor. The resonant frequency is then the frequency when there is no phase difference. A Q-meter may be used for this purpose.

4.11.1.3 Method 2

4.11.1.3.1 General

For this measuring method, use shall be made of an absorption oscillator-wavemeter (grid dip meter).

4.11.1.3.2 Mounting of capacitors with terminations for general use

Four capacitors of nearly equal value and configuration shall be soldered in series at right angles to form a closed loop. The wires shall be of the specified length and no additional wiring or connections shall be employed (see Figure 5). This loop shall be coupled as loosely as possible to an absorption oscillator-wavemeter and the resonant frequency shall then be determined.

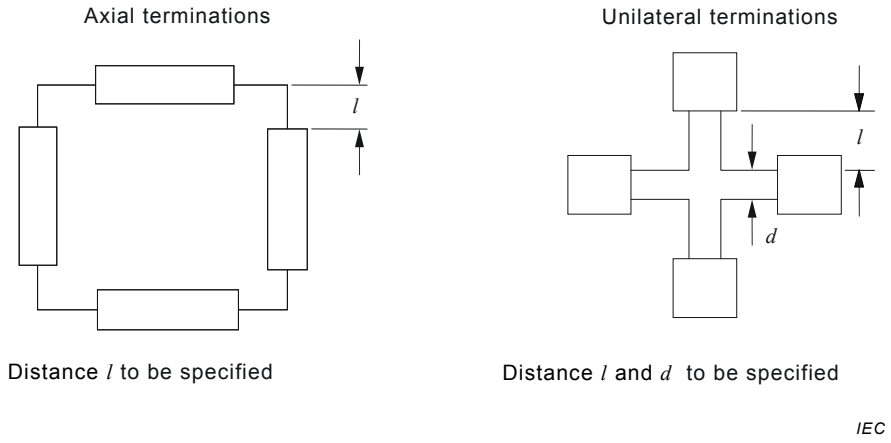


Figure 5 – Capacitor mounting arrangement

4.11.1.3.3 Mounting of capacitors with terminations for printed circuit use

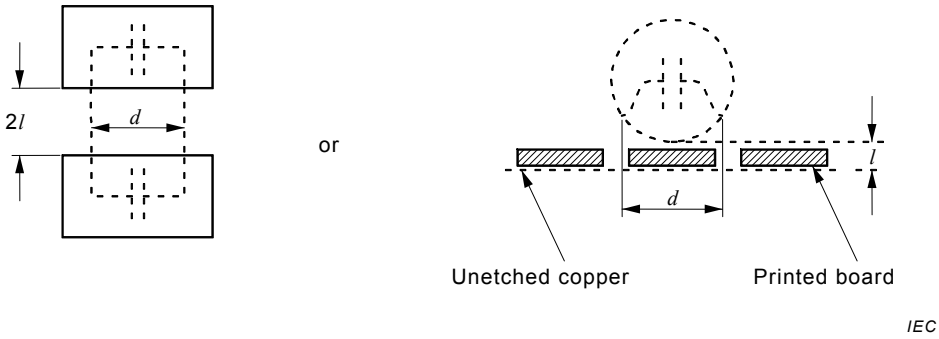
To determine the resonant frequency under the conditions of the capacitor being mounted on a printed circuit board and where the configuration of the case and/or the terminations does not permit a four capacitor loop to be formed correctly, the loop shall be by formed by two (nearly) identical capacitors with straight terminations of specified length (see Figure 6).

The second capacitor may be substituted by its mirror image on a conductive plane in the following way.

A copper-clad, unetched sheet of printed circuit base material, whose edges are at least three times as long as the maximum dimension of the capacitor is drilled in its centre to accommodate the capacitor in its normal way.

The relevant specification shall prescribe the details of mounting. The capacitor is soldered in place with the capacitor being short-circuited by the copper laminate. Then the capacitor is coupled to the search coil and measured as in 4.11.1.3.5.

Metal-cased capacitors may necessitate special arrangements for coupling, which should be prescribed in the relevant specification.



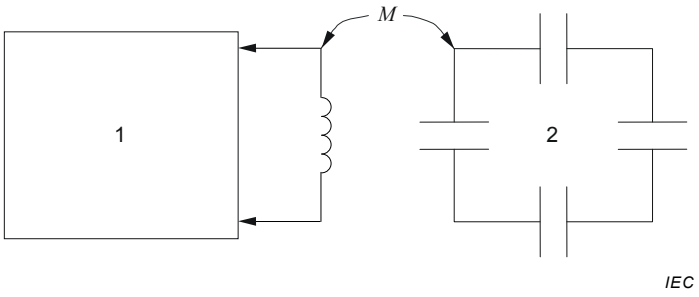
Distances l and d to be specified, where l is to be measured from the seating plane.

Figure 6 – Capacitor mounting arrangement

4.11.1.3.4 Description of the method

The absorption oscillator-wavemeter is a variable frequency L-C oscillator with the inductor formed as an external search coil. When the search coil is coupled into another resonant circuit, power is absorbed causing a change in the mean grid (gate on FETs (field effect transistor)) voltage. This is monitored and hence "dips" at the resonant frequency of the coupled circuit. This coupled circuit consists of four capacitors mounted as described in 4.11.1.3.2 and connected in series to minimize the mutual inductance.

A typical diagram showing the use of an absorption oscillator-wavemeter is given in Figure 7.



Key

1 absorption oscillator-wavemeter (grid-dip meter)

2 coupled resonant circuit

M coupling factor

Figure 7 – Typical diagram of an absorption oscillator-wavemeter

4.11.1.3.5 Use of the absorption oscillator-wavemeter

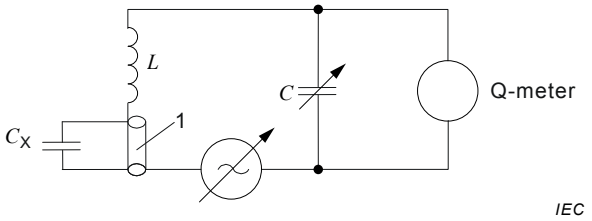
With the search coil of the wavemeter close to the capacitors under investigation, the resonant frequency is approached from a lower frequency. Dips should be checked by moving the wavemeter away from the capacitors (reducing the absorbed power) to make sure the dip is not due to internal effects of the wavemeter. The resonant frequency should be measured with as loose a coupling as is practical to avoid pulling the oscillator.

4.11.1.3.6 Requirements

The resonant frequency shall not exceed the limits prescribed in the relevant specification.

4.11.1.4 Method 3

This method is particularly suitable for capacitors of low capacitance and with a self-resonant frequency within Q-meter operating range. Using a Q-meter and the circuit shown in Figure 8, the lowest frequency shall be determined at which the same resonant frequency is obtained, whether the capacitor shorting strap is in place or not. This frequency can be shown to be equal to the self-resonant frequency of the capacitor.



Key

1 shorting strap

C_X capacitor under test

C variable capacitor

L inductor

Q Q-meter

Figure 8 – Schematic diagram of the measuring circuit

4.11.2 Inductance

The series inductance L_X of a capacitor is calculated from the measured self-resonant frequency f_r of the capacitor using the formula given below:

$$L_X = \frac{1}{4\pi^2 \times f_r^2 \times C_X}$$

where C_X is the capacitance of the capacitor measured in accordance with 4.7 and the requirements of the relevant sectional specification.

4.11.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) which test method is preferred;

b) the lead length of the capacitor to be employed in the measurement;

c) any special mounting arrangement;

d) the limits of series inductance or self-resonant frequency.

4.12 Outer foil termination

The correct indication of the termination which is connected to the outside metal foil shall be checked in such a way that the capacitor is not damaged.

A suitable method is given in Figure 9.

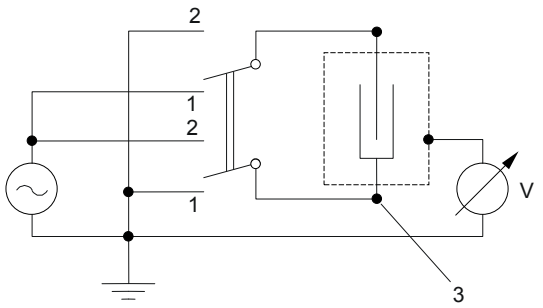
The frequency of the generator may be from 50 Hz to a few thousand Hertz and shall be so chosen as to give a clear result of measurement, the most appropriate value being dependent on the type of capacitor under test.

The voltage shall be of the order of 10 V.

The voltmeter shall have an input impedance of not less than 1 MΩ.

The stray capacitance of the wiring shall be kept low.

With the switch in position 1, the deflection of the voltmeter shall be markedly less than with the switch in position 2.



Key

1, 2 switching terminations

3 outer foil terminations

V voltmeter

Figure 9 – Test circuit

4.13 Robustness of terminations

4.13.1 General

The capacitors shall be subjected to IEC 60068-2-21, Tests Ua_1, Ub, Uc, and Ud, as applicable.

4.13.2 Test Ua_1 – Tensile

The force applied shall be:

– for terminations other than wire terminations: 20 N;
– for wire terminations: see Table 4.

Table 4 – Tensile force

Nominal cross-sectional area (S) [a] mm^2	Corresponding diameter (d) for circular-section wires mm	Force with tolerance of ± 10 % N
$S \leq 0{,}05$	$d \leq 0{,}25$	1
$0{,}05 < S \leq 0{,}1$	$0{,}25 < d \leq 0{,}35$	2,5
$0{,}1 < S \leq 0{,}2$	$0{,}35 < d \leq 0{,}5$	5
$0{,}2 < S \leq 0{,}5$	$0{,}5 < d \leq 0{,}8$	10
$0{,}5 < S \leq 1{,}2$	$0{,}8 < d \leq 1{,}25$	20
$1{,}2 < S$	$1{,}25 < d$	40

[a] For circular-section wires, strips or pins: the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification. For stranded wires, the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the relevant specification.

4.13.3 Test Ub – Bending (half of the sample)

Method 1: Two consecutive bends shall be applied in each direction. This test shall not apply if, in the detail specification, the terminations are described as rigid.

4.13.4 Test Uc – Torsion (remaining sample)

Method 1, severity 2 (two successive rotations of 180°) shall be used.

This test shall not apply if in the detail specification the terminations are described as rigid and to components with unidirectional terminations designed for printed wiring applications.

4.13.5 Test Ud – Torque

This test shall apply to capacitors for terminations with threaded studs or screws and for integral mounting devices. Torque and severity shall be selected from Table 5.

Table 5 – Torque

Severity	Torque Nm								
	Nominal thread diameter mm								
	2,6	3	3,5	4	5	6	8	10	12
1	0,4	0,5	0,8	1,2	2,0	2,5	5	7	12
2	0,2	0,25	0,4	0,6	1,0	1,25	2,5	3,5	6

4.13.6 Visual examination

After each of these tests, the capacitors shall be visually examined. There shall be no visible damage.

4.14 Resistance to soldering heat

4.14.1 Preconditioning and initial measurement

When prescribed in the relevant specification, the capacitors shall be dried using the method of 4.3.

The capacitors shall be measured as prescribed in the relevant specification.

4.14.2 Test procedure

Unless otherwise stated in the relevant specification, one of the following tests as set out in the same specification shall be applied.

The test conditions shall be defined in the relevant specification.

a) For all capacitors except those of item b) and c) below:
IEC 60068-2-20, Test Tb, method 1 (solder bath).

b) For capacitors not designed for use in printed boards, but with connections intended for soldering as indicated by the detail specification:

   1) IEC 60068-2-20, Test Tb, method 1 (solder bath),

   2) IEC 60068-2-20, Test Tb, method 2 (soldering iron).

c) For surface mount capacitors
IEC 60068-2-58, reflow or solder bath method.

4.14.3 Recovery

The period of recovery shall, unless otherwise specified in the detail specification, be not less than 1 h nor more than 2 h, except for surface mount capacitors, for which the period of recovery shall be 24 h ± 2 h.

4.14.4 Final inspection, measurement and requirements

For all capacitors, except surface mount capacitors, the following shall apply:

– when the test has been carried out the capacitors shall be visually examined;

– there shall be no visible damage and the marking shall be legible;

– the capacitors shall then be measured as prescribed in the relevant specification.

Surface mount capacitors shall be visually examined and measured and shall meet the requirements as prescribed in the relevant specification.

4.15 Solderability

4.15.1 General

This test shall not be applied to those terminations which the detail specification describes as not designed for soldering.

4.15.2 Preconditioning

The relevant specification shall prescribe whether ageing is to be applied. If accelerated ageing is required, one of the ageing procedures given in IEC 60068-2-20 shall be applied.

Unless otherwise stated in the relevant specification, the test shall be carried out with non-activated flux.

4.15.3 Test procedure

Unless otherwise stated in the relevant specification, one of the following tests as set out in the same specification shall be applied.

The test conditions shall be defined in the relevant specification.

a) For all capacitors except those of item b) and c) below:
   1) IEC 60068-2-20, Test Ta, method 1 (solder bath)

      Depth of immersion (from the seating plane or component body):
      2,0 mm $^{0}_{-0,5}$ mm, using a thermal insulating screen of 1,5 mm ± 0,5 mm thickness;
   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron)
   3) IEC 60068-2-54, solder bath wetting balance method.

      NOTE IEC 60068-2-54 is applicable only when prescribed in the detail specification or when agreed upon between manufacturer and customer.

b) For capacitors not designed for use in printed boards, but with connections intended for soldering as indicated by the detail specification:
   1) IEC 60068-2-20, Test Ta, method 1 (solder bath)

      Depth of immersion (from the seating plane or component body): 3,5 mm $^{0}_{-0,5}$ mm.
   2) IEC 60068-2-20, Test Ta, method 2 (soldering iron).

c) For surface mount capacitors
   1) IEC 60068-2-58, reflow or solder bath method
   2) IEC 60068-2-69, solder bath wetting balance or solder globule wetting balance method.

      NOTE IEC 60068-2-69 is applicable only when prescribed in the detail specification or when agreed upon between manufacturer and customer.

4.15.4 Final inspection, measurements and requirements

The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations.

The capacitors shall meet the requirements as prescribed in the relevant specification.

4.16 Rapid change of temperature

4.16.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.16.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-14, Test Na, using the degree of severity as prescribed in the relevant specification.

4.16.3 Final inspection, measurements and requirements

After recovery, the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.17 Vibration

4.17.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.17.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-6, Test Fc, using the mounting method and the degree of severity prescribed in the relevant specification.

4.17.3 Electrical test (intermediate measurement)

When specified in the detail specification, during the last 30 min of the vibration test an electrical measurement shall be made in each direction of movement to check intermittent contacts, or open or short circuits.

The method of measurement shall be prescribed in the detail specification.

The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

4.17.4 Final inspection, measurements and requirements

After the test the capacitors shall be visually examined. There shall be no visible damage. When capacitors are tested as specified in 4.17.3, the requirements shall be stated in the detail specification.

The measurements prescribed in the relevant specification shall then be made.

4.18 Bump (repetitive shock)

4.18.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.18.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-27, Test Ea (repetitive shock), using the mounting method and the severity prescribed in the relevant specification.

Preferred conditions are:

- pulse shape: half-sine;
- number of shocks in each direction: a minimum of 100;
- peak acceleration: to be chosen from recommended severities.

4.18.3 Final inspection, measurements and requirements

After the test, the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.19 Shock

4.19.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.19.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-27, Test Ea (non-repetitive shock), using the mounting method and the severity prescribed in the relevant specification.

4.19.3 Final inspection, measurements and requirements

After the test the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.20 Container sealing

The capacitors shall be subjected to the procedure of the appropriate method of IEC 60068-2-17, Test Q, as prescribed in the relevant specification.

4.21 Climatic sequence

4.21.1 General

In the climatic sequence, an interval of a maximum of three days is permitted between any of the tests, except that the cold test shall be applied immediately after the recovery period for the first cycle of the damp heat, cyclic, IEC 60068-2-30, Test Db.

4.21.2 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.21.3 Dry heat

The capacitors shall be subjected to IEC 60068-2-2, Test Bb, for 16 h, using the degree of severity of the upper category temperature, as prescribed in the detail specification.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the upper category temperature.

While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the relevant specification shall be made.

After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 4 h.

4.21.4 Damp heat, cyclic, Test Db, first cycle

The capacitors shall be subjected to IEC 60068-2-30, Test Db, for one cycle of 24 h, using a temperature of 55 °C (severity b).

Unless otherwise specified in the relevant specification, variant 2 shall be used.

After recovery the capacitors shall be subjected immediately to the cold test.

4.21.5 Cold

The capacitors shall be subjected to IEC 60068-2-1, Test Ab, for 2 h, using the degree of severity of the lower category temperature, as prescribed in the relevant specification.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the lower category temperature.

While still at specified low temperature and at the end of the period of low temperature, the measurements prescribed in the relevant specification shall be made.

After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 4 h.

4.21.6 Low air pressure

The capacitors shall be subjected to IEC 60068-2-13, Test M, using the appropriate degree of severity prescribed in the relevant specification. The duration of the test shall be 10 min, unless otherwise stated in the relevant specification.

The relevant specification shall prescribe:

a) duration of test; if other than 10 min;

b) temperature;

c) degree of severity.

While at the specified low pressure, the rated voltage shall be applied during the last 60 s of the test period, unless otherwise prescribed in the relevant specification.

During and after the test, there shall be no evidence of permanent breakdown, flashover, harmful deformation of the case, or seepage of impregnant.

4.21.7 Damp heat, cyclic, Test Db, remaining cycles

The capacitors shall be subjected to IEC 60068-2-30, Test Db, for the following number of cycles of 24 h as indicated in Table 6, under the same conditions as used for the first cycle.

Table 6 – Number of cycles

Climatic categories	Number of cycles
-/-/56	5
-/-/21	1
-/-/10	1
-/-/04	None

4.21.8 Final measurements

After the prescribed recovery, the measurements prescribed in the relevant specification shall be made.

4.22 Damp heat, steady state

4.22.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.22.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-78, Test Cab, using the degree of severity corresponding to the climatic category of the capacitor as indicated in the detail specification. The temperature and humidity of test shall be (40 ± 2) °C, (93 ± 3) %RH, unless otherwise specified in the relevant specification.

When specified in the blank detail specification, the detail specification may specify the application of a polarizing voltage during the whole period of damp heat conditioning. For metallized film capacitors this test should be carried out in accordance with Annex G.

With the exception of electrolytic capacitors, within 15 min after removal from the test chamber, the voltage proof test of 4.6 shall be carried out at test point A only, using the rated voltage, unless otherwise specified in the detail specification.

4.22.3 Final inspection, measurements and requirements

After recovery, the capacitors shall be visually examined. There shall be no visible damage. The measurements prescribed in the relevant specification shall then be made.

In case of testing metallized film capacitors, when specified in the blank detail specification, the permissible deviation of the average C-value of test group with and the test group without d.c. voltage shall be described in the relevant detail specification.

4.23 Endurance

4.23.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.23.2 Test procedure

The tests of IEC 60068-2-2 apply as follows:

a) d.c. tests – Test Bb;

b) a.c. tests – Test Bb or Bd as applicable;

c) pulse tests – Test Bb or Bd as applicable.

The test specimens may be introduced into the chamber at any temperature, from laboratory temperature to the upper category temperature, but the voltage shall not be applied to the capacitor before it has reached the chamber temperature.

4.23.3 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) duration of the test (for example, hours or number of pulses);

b) test temperature (for example, room, rated or upper category temperature);

c) voltage and/or current to be applied (see also 4.23.4).

When capacitors have to meet additional requirements for electric shock hazard protection, additional test conditions for endurance testing (for example, pulse voltage application) shall be prescribed in the relevant specification.

4.23.4 Test voltage

Unless otherwise specified in the relevant specification, the voltage to be applied during the test shall be selected from the following.

a) d.c. tests

   The test shall be carried out at a multiplying factor times the rated voltage (d.c.) at temperatures up to the rated temperature. The test temperature and the value of the multiplying factor shall be specified in the relevant specification. For tests at the upper category temperature the derating factor for the voltage shall also be given.

b) a.c. tests (sinusoidal voltage)

   The test shall be made at 50 Hz to 60 Hz and at a multiplying factor times the rated voltage (a.c.) (see 2.3.4 a)) at temperatures up to the rated temperature, or at the upper category temperature with a derating factor for the voltage. The test temperature and the

value of the multiplying factor/derating factor for the voltage shall be specified in the relevant specification.

c) a.c. tests (sinusoidal current)

This test shall be made with a current applied in accordance with 2.3.4 b). The test temperature, the value of current and frequency shall be specified in the relevant specification.

To facilitate testing, the test may be made with a voltage of specified frequency applied to a group of capacitors in parallel or in series/parallel.

d) sinusoidal a.c. tests (reactive power)

This test shall be made with reactive power in accordance with 2.3.4 c). The test temperature, the value of the reactive power, and the frequency shall be specified in the relevant specification.

To facilitate testing, the test may be made with a voltage of specified frequency applied to a group of capacitors in parallel or in series/parallel.

A thermal stability test (see 4.30) may constitute an alternative to this test. The test to be carried out shall be specified in the detail specification.

e) pulse tests

This test shall be made with pulses applied in accordance with 2.3.5 and as specified in the relevant specification. Guidance for pulse tests is given in Annex E.

f) sinusoidal a.c. or pulse tests with superimposed d.c.

Tests b) to e) may be carried out with superimposed d.c. as required in the relevant specification (see also 2.2.23).

An example of a test circuit suitable for electrolytic capacitors is given in Figure 10.

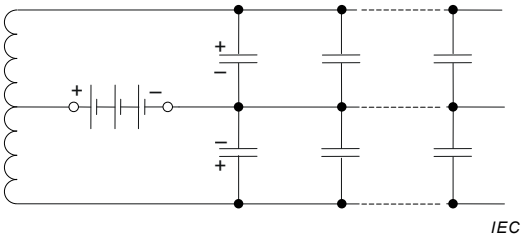


Figure 10 – Test circuit for electrolytic capacitors

4.23.5 Placement in the test chamber

The capacitors shall be placed in the test chamber in such a manner that

a) for heat dissipating capacitors, no capacitor is within 25 mm of any other capacitor,

b) for non-heat dissipating capacitors, no capacitor is within 5 mm of any other capacitor.

4.23.6 Recovery

After the specified period, the capacitors shall be allowed to cool to standard atmospheric conditions for testing and where specified in the relevant specification, the capacitors shall be subjected to recovery.

4.23.7 Final inspection, measurements and requirements

The capacitors shall then be visually examined.

The measurements prescribed in the relevant specification shall then be made. A capacitor shall be considered to have failed when the requirements of the relevant specification during or at the end of the test are not satisfied.

4.24 Variation of capacitance with temperature

4.24.1 Static method

4.24.1.1 Initial measurement

Measurements of capacitance shall be made under the conditions prescribed in the relevant specification.

4.24.1.2 Test procedure

The capacitor shall be maintained at each of the following temperatures in turn:

a) 20 °C ± 2 °C;

b) lower category temperature ±3 °C;

c) intermediate temperatures, if required in the detail specification;

d) 20 °C ± 2 °C;

e) intermediate temperatures, if required in the detail specification;

f) upper category temperature ±2 °C;

g) 20 °C ± 2 °C.

If required for a particular type of capacitor, the relevant specification shall prescribe whether thermal shock is to be avoided or whether a maximum rate of change of temperature shall be specified.

The conditions of measurement, during or after temperature cycling, a description of the temperature cycle and the number of cycles, should be stated.

4.24.1.3 Measuring method

Capacitance measurements shall be made at each of the temperatures specified above, after the capacitor has reached thermal stability.

The condition of thermal stability is judged as having been reached when two readings of capacitance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The measurement of the actual temperature shall be made with a precision compatible with the requirements of the detail specification.

Care shall be taken during measurements to avoid condensation or frost on the surface of the capacitors.

4.24.1.4 Reduced procedure

For the lot-by-lot quality conformance testing, the detail specification may prescribe a reduced procedure, for example, measurements d), f) and g) in 4.24.1.2 covering the temperature range from 20 °C to the upper category temperature.

4.24.2 Dynamic method

As an alternative to the static method of 4.24.1, a dynamic plotting method may be employed. The capacitors shall be subjected to a slowly varying temperature.

A temperature-sensing device shall be embedded in a dummy capacitor to be included with the capacitor under test in a manner that will ensure that the measured temperature is the

same as that occurring in the capacitor under test. The capacitance shall be measured using a self-balancing bridge or comparator.

The output of the bridge or comparator shall be coupled to the "Y" axis of a plotting table.

The output of the temperature sensing device shall be coupled to the "X" axis of a plotting table.

The temperature shall be varied slowly enough to produce a uniform curve with no loop at the lower or upper category temperature. The temperature shall be varied subsequently from 20 °C to the lower category temperature, then to the upper category temperature and back to 20 °C. Two cycles shall be carried out.

This method may be employed only when it can be demonstrated that the results are the same as for the method employing stabilized temperatures.

In case of dispute, the static method shall be used.

4.24.3 Methods of calculation

4.24.3.1 General

The following applies:

C_0 is the capacitance measured at point d) of 4.24.1.2;

T_0 is the temperature measured at point d) of 4.24.1.2;

C_i is the capacitance measured at the test temperature, other than at points a), d) and g) of 4.24.1.2;

T_i is the temperature measured on test.

4.24.3.2 Temperature characteristics of capacitance

The variation of capacitance as a function of temperature shall be calculated for all the values of C_i as follows:

$$\frac{\Delta C}{C_0} = \frac{C_i - C_0}{C_0}$$

The variation of capacitance is normally expressed in per cent.

4.24.3.3 Temperature coefficient of capacitance and temperature cyclic drift of capacitance

Temperature coefficient of capacitance and temperature cyclic drift of capacitance shall be calculated as follows:

a) **Temperature coefficient of capacitance (α)**

Temperature coefficient of capacitance (α) shall be calculated for all the values of C_i as follows:

$$\alpha_i = \frac{C_i - C_0}{C_0(T_i - T_0)} \times 10^6$$

The temperature coefficient is normally expressed in parts per million per Kelvin (10^{-6}/K).

b) **Temperature cyclic drift of capacitance**

The temperature cyclic drift of capacitance shall be calculated for the points of measurement of 4.24.1.2 a), d) and g) in the following manner:

$$\delta_{da} = \frac{C_0 - C_a}{C_0}$$

$$\delta_{gd} = \frac{C_g - C_0}{C_0}$$

$$\delta_{ga} = \frac{C_g - C_a}{C_0}$$

as required in the relevant specification. The largest of these values is the "temperature cyclic drift of capacitance".

The capacitance drift is normally expressed in per cent.

4.25 Storage

4.25.1 Storage at high temperature

4.25.1.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.25.1.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-2, Test Bb, using the following severities:

– temperature: upper category temperature;

– duration: 96 h ± 4 h.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to the upper category temperature.

4.25.1.3 Final inspection, measurements and requirements

After recovery for at least 16 h, the measurements prescribed in the relevant specification shall be made.

4.25.2 Storage at low temperature

4.25.2.1 Initial measurement

The measurements prescribed in the relevant specification shall be made.

4.25.2.2 Test procedure

The capacitors shall be subjected to IEC 60068-2-1, Test Ab. The capacitors shall be stored at –40 °C for either a period of 4 h after thermal stability has been reached, or for 16 h, whichever is the shorter period.

The test specimens may be introduced into the chamber at any temperature from laboratory temperature to –40 °C.

4.25.2.3 Final inspection, measurements and requirements

After recovery for at least 16 h, the measurements prescribed in the relevant specification shall be made.

4.26 Surge

4.26.1 Initial measurement

The measurements specified in the relevant specification shall be made.

4.26.2 Test procedure

Suitable test circuits are shown in Figure 11 and Figure 12.

NOTE The thyristor circuit has the advantage of high repetition rates and is free from troubles associated with dirty contacts and contact bounce.

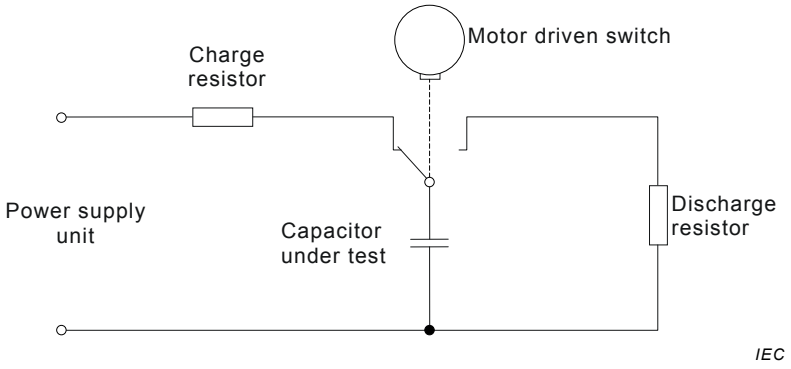


Figure 11 – Relay circuit

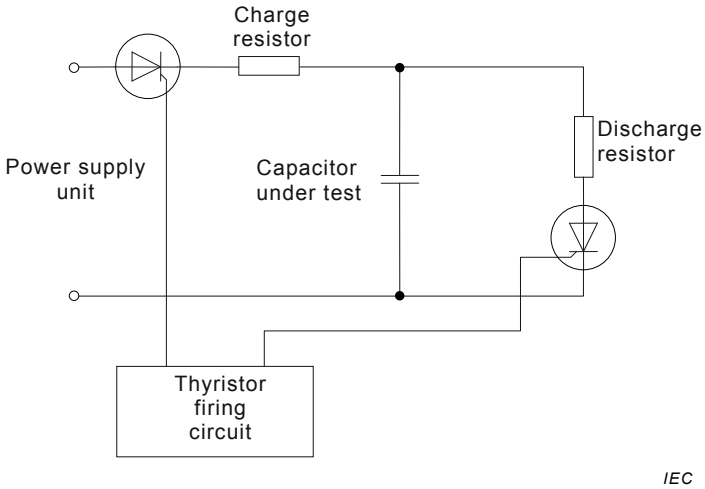
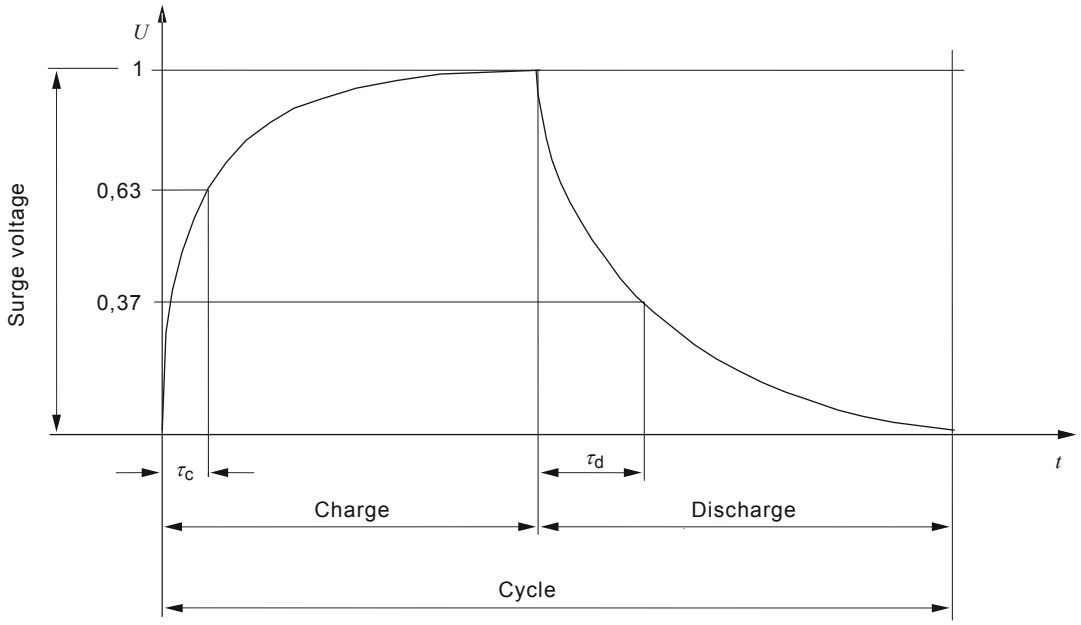


Figure 12 – Thyristor circuit

The voltage waveform across the capacitor under test shall be approximately as shown in Figure 13.



τ_c = charge time constant
τ_d = discharge time constant

IEC

Figure 13 – Voltage waveform across capacitor

4.26.3 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.26.4 Information to be given in the relevant detail specification

The following information shall be given in the relevant specification:

a) the charge time constant arising from the internal resistance of the power supply and the resistance of the charge circuit and the capacitance of the capacitor under test;
b) the discharge time constant arising from the resistance of the discharge circuit and the capacitance of the capacitor under test;
c) the ratio of the surge voltage to rated or category voltage (as appropriate);

   The number of times per hour that this voltage may be applied should be specified.
d) the number of cycles of test;
e) the duration of the charge period;
f) the duration of the discharge period;
g) the repetition rate (cycles per second);
h) temperature, if different from standard atmospheric conditions for testing.

4.27 Charge and discharge tests and inrush current test

4.27.1 Initial measurement

The measurements specified in the relevant specification shall be made.

4.27.2 Test procedure

Suitable test circuits are given in 4.26.2, Figure 11 and Figure 12.

The voltage and current waveforms across and through the capacitor under test are approximately as shown in Figure 14.

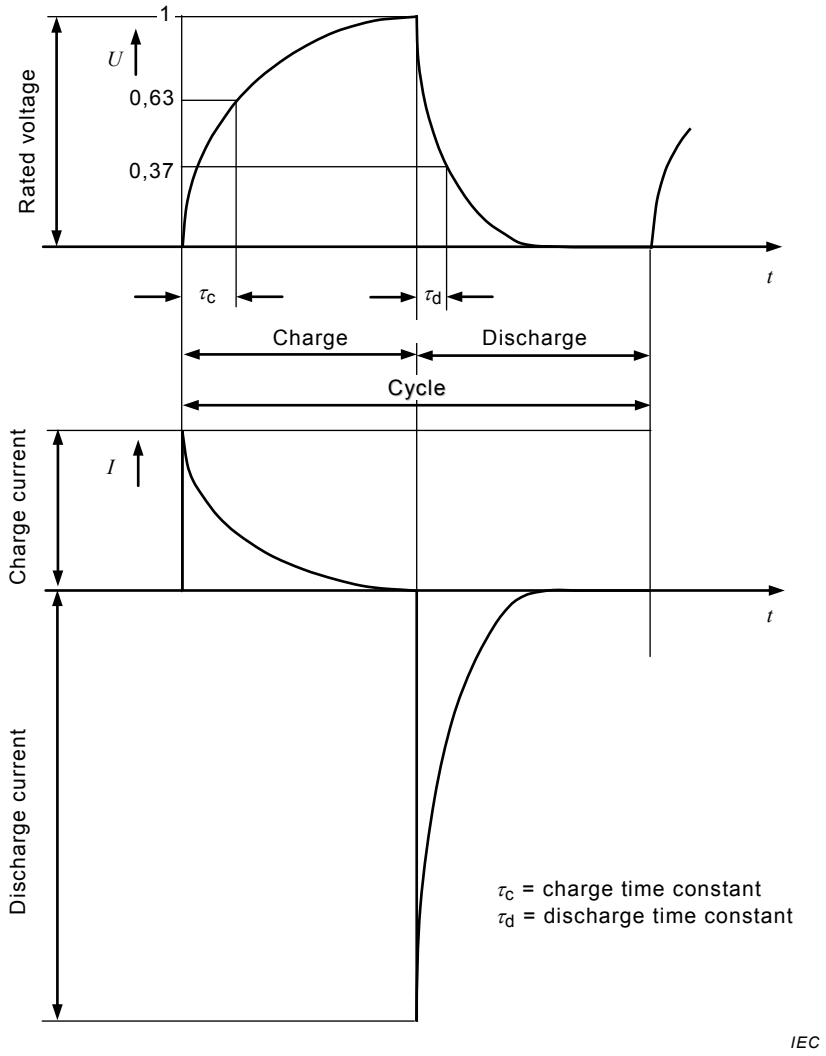


Figure 14 – Voltage and current waveform

4.27.3 Charge and discharge

The following information shall be given in the relevant specification:

a) the charge time constant arising from the internal resistance of power supply and the resistance of the charge circuit and the capacitance of the capacitor under test;

b) the discharge time constant arising from the resistance of the discharge circuit and the capacitance of the capacitor under test;

c) the voltage to be applied during the charge period, if different from the rated voltage;

d) the number of cycles of test;

e) the duration of the charge period;

f) the duration of the discharge period;

g) the repetition rate (cycles per second);

h) temperature, if different from standard atmospheric conditions for testing.

4.27.4 Inrush current

The following information shall be given in the relevant specification:

a) the peak charge current;
b) the voltage to be applied during the charge period if different from the rated voltage;
c) the number of cycles of test;
d) the duration of the charge period in milliseconds;
e) the duration of the discharge period;
f) the repetition rate;
g) the temperature if different from standard atmospheric conditions for testing.

4.27.5 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.28 Pressure relief (for aluminium electrolytic capacitors)

4.28.1 General

Unless otherwise specified in the relevant specification, one of the following tests shall be used to test the pressure relief device of the capacitors.

4.28.2 AC test

Applied voltage: alternating voltage with r.m.s. value not exceeding 0,7 times the rated direct voltage.

Frequency of the applied voltage: 50 Hz or 60 Hz.

Series resistor: R = 0,5 times the impedance of the capacitor at the test frequency.

4.28.3 DC test

Applied voltage: direct voltage applied in the reverse direction, of an amplitude necessary to produce a current of 1 A to 10 A.

4.28.4 Pneumatic test

Applied pneumatic pressure: gas pressure introduced from outside shall be increased at a rate of 20 kPa/s continuously.

4.28.5 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.29 Characteristics at high and low temperature

4.29.1 Test procedure

The capacitors shall be subjected to the procedures of the dry heat and cold test (4.21.3 and 4.21.5, respectively) with the following details.

The degree of severity for these tests shall be the same as for the dry heat and cold tests. Tests at intermediate temperatures may be prescribed in the relevant specification.

Measurements shall be made at each of the specified temperatures after the capacitor has reached thermal stability.

The condition of thermal stability is judged to be reached when two readings of a characteristic, taken in an interval of not less than 5 min, do not differ by an amount greater than that which can be attributed to the measuring apparatus.

4.29.2 Requirements

The capacitors shall not exceed the limits prescribed in the relevant specification.

4.30 Thermal stability test

A thermal stability test may constitute an alternative to the endurance test in accordance with 4.23.4 d). The test to be carried out shall be specified in the detail specification.

The capacitor shall be loaded with a specified factor times the rated reactive power dissipation at the rated temperature and duration as specified in the relevant specification.

A test for thermal stability shall be made by measuring the temperature rise as a function of time over the last part of the specified duration. The temperature rise shall be within specified limits.

The measurement of the temperature rise may be made by the use of a thermocouple, thermistor, infrared thermometer, infrared photography, etc. Care should be taken to ensure that the error of measurement does not exceed ±1 °C and that errors due to heat conduction along measuring connections are kept to a minimum.

The relevant specification shall specify the point at which the measurements shall be made and the method of mounting (see IEC 60068-2-2:2007, 6.4).

4.31 Component solvent resistance

4.31.1 Initial measurements

The measurements prescribed in the relevant specification shall be made.

4.31.2 Test procedure

The components shall be subjected to IEC 60068-2-45, Test XA, with the following details:

a) solvent to be used: IPA (IEC 60068-2-45:1980/AMD1:1993, 3.1.2);
b) solvent temperature: 23 °C ± 5 °C, unless otherwise specified in the detail specification;
c) conditioning: method 2, (without rubbing);
d) recovery time: 48 h, unless otherwise stated in the detail specification.

4.31.3 Final inspection, measurements and requirements

The measurements prescribed in the relevant specification shall then be made and the specified requirements be met.

4.32 Solvent resistance of marking

4.32.1 Test procedure

The components shall be subjected to IEC 60068-2-45, Test XA, with the following details:

a) solvent to be used: IPA (IEC 60068-2-45:1980/AMD1:1993, 3.1.2);

b) solvent temperature: 23 °C ± 5 °C;

c) conditioning: method 1 (with rubbing);

d) rubbing material: cotton wool;

e) recovery time: not applicable, unless otherwise stated in the detail specification.

4.32.2 Final inspection, measurements and requirements

After the test the marking shall be legible.

4.33 Mounting (for surface mount capacitors only)

4.33.1 Substrate

Surface mount capacitors shall be mounted on a suitable substrate, the method of mounting being dependent on the capacitor construction. The substrate material shall normally be an epoxide woven glass fabric laminated printed board (as defined in IEC 61249-2-7) with a thickness of 1,6 mm ± 0,20 mm or 0,8 mm ± 0,10 mm, or a 90 % to 98 % alumina substrate having a thickness of 0,635 mm ± 0,05 mm or more, and shall not affect the result of any test or measurement. The detail specification shall indicate which material is to be used for the electrical measurements.

The substrate shall have metallized land areas of proper spacing to permit mounting of surface mount capacitors and shall provide electrical connection to the surface mount capacitor terminals. The details shall be specified in the detail specification.

Examples of test substrates for mechanical and electrical tests are shown in Figure 15 and Figure 16, respectively.

If another method of mounting applies, the method should be clearly described in the detail specification.

4.33.2 Wave soldering

When the detail specification specifies wave soldering, suitable glue, details of which may be specified in the detail specification, shall be used to fasten the component to the substrate before soldering is performed.

Small dots of the glue shall be applied between the conductors of the substrate by means of a suitable device securing repeatable results.

The surface mount capacitors shall be placed on the dots using tweezers. To ensure that no glue is applied to the conductors, the surface mount capacitors shall not be moved about.

The substrate with the surface mount capacitors shall be heat-treated in an oven at 100 °C for 15 min.

The substrate shall be soldered in a wave soldering apparatus. The apparatus shall be adjusted to have a pre-heating temperature of 80 °C to 100 °C, a solder bath at 260 °C ± 5 °C and a soldering time of 5 s ± 0,5 s.

The substrate shall be cleaned for 3 min in a suitable solvent (see IEC 60068-2-45:1980/ AMD1:1993, 3.1.2).

4.33.3 Reflow soldering

When the detail specification specifies reflow soldering, the following mounting procedure applies.

a) The solder used in preform or paste form shall be silver bearing (2 % minimum) eutectic Sn/Pb solder together with a flux as stated in IEC 60068-2-20. Alternative solders such as 60/40 or 63/37 may be used on chips whose construction includes solder leach barriers. Pb-free solder used in preform or paste form shall be Sn96,5Ag3,0Cu0,5 or derivative solder together with a flux as stated in IEC 60068-2-58, or as defined in the relevant specification.

b) The surface mount capacitor shall then be placed across the metallized land areas of the test substrate so as to make contact between surface mount and substrate land areas.

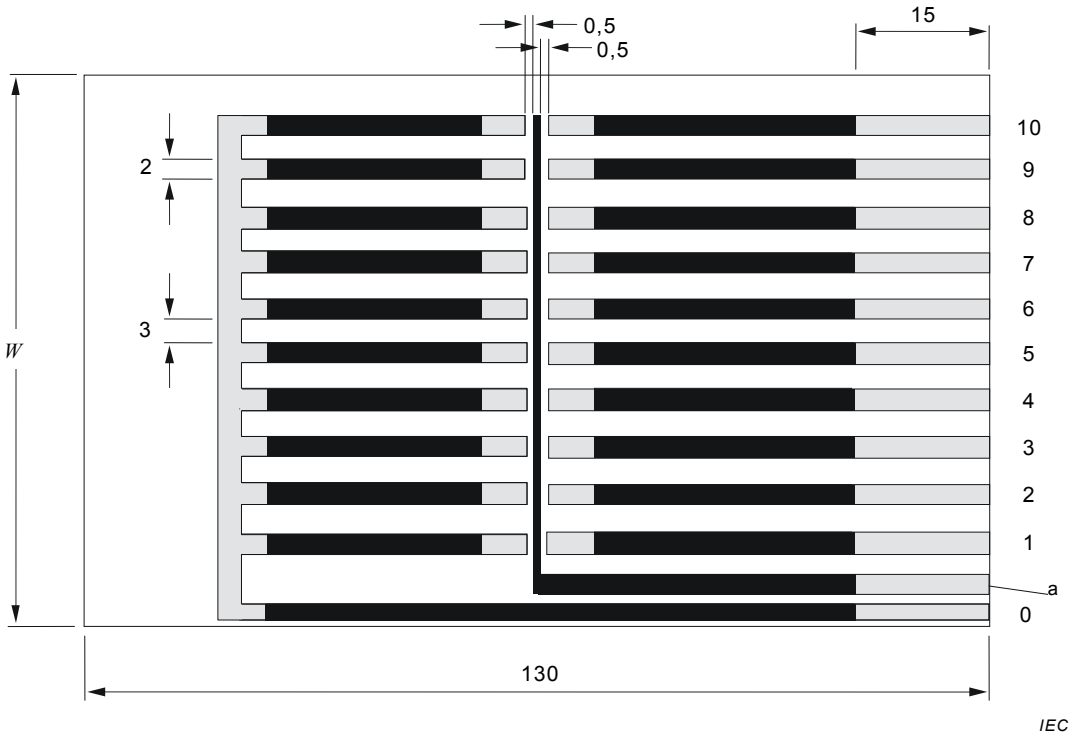
c) The substrate shall then be placed in or on a suitable heating system (molten solder, hot plate, tunnel oven, etc.). The temperature of the unit shall be maintained between 215 °C and 260 °C, until the solder melts and reflows forming a homogeneous solder bond, but for not longer than 10 s.

Flux should be removed by a suitable solvent (see IEC 60068-2-45:1980/AMD1:1993, 3.1.2). All subsequent handling should be such as to avoid contamination. Care should be taken to maintain cleanliness in test chambers and during post test measurements.

The detail specification may require a more restricted temperature range.

If vapour phase soldering is applied, the same method may be used with the temperatures adapted.

A suitable substrate for mechanical tests is shown in Figure 15. Note that this substrate may not be suitable for impedance measurements. A suitable substrate for electrical tests is shown in Figure 16.



Key

Solderable areas
Non-solderable areas (covered with non-solderable lacquer)

All dimensions are in millimetres. Tolerances: medium.

Material: epoxide woven glass

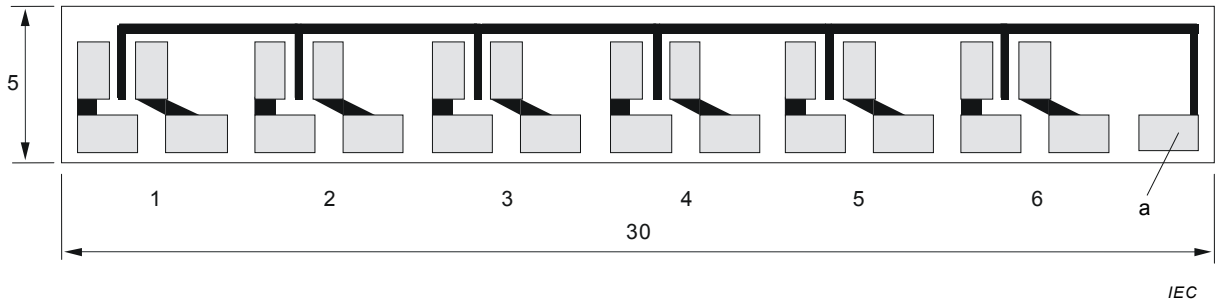
Thickness: 1,6 mm ± 0,20 mm, or 0,8 mm ± 0,10 mm

Dimensions not given should be chosen according to the design and size of the specimens to be tested.

Dimension W is dependent on the design of the test equipment.

[a] This conductor may be omitted or used as a guard electrode.

Figure 15 – Suitable substrate for mechanical tests



Key

Solderable areas
Non-solderable areas (covered with non-solderable lacquer)

All dimensions are in millimetres. Tolerances: medium.

Material: 90 % to 98 % alumina substrate

Thickness: 0,635 mm ± 0,05 mm, or more

Dimensions not given should be chosen according to the design and size of the specimens to be tested.

Dimension W depends on the design of the test equipment.

[a] This conductor may be omitted or used as a guard electrode.

Figure 16 – Suitable substrate for electrical tests

4.34 Shear test

4.34.1 Test procedure

The surface mount capacitors shall be mounted as described in IEC 60068-2-21, Test U.

The capacitors shall be subjected to IEC 60068-2-21, Test Ue3, under the following condition.

A force shall be applied to the surface mount capacitor body progressively, without shock, and shall be maintained for a period of 10 s ± 1 s. Unless otherwise specified in the relevant specification, a force shall be selected from 1 N, 2 N, 5 N or 10 N.

4.34.2 Final inspection, measurements and requirements

The surface mount capacitors shall be visually examined in the mounted state. There shall be no visible damage.

4.35 Substrate bending test

4.35.1 Test procedure

The surface mount capacitor shall be mounted on an epoxide woven glass printed board as described in 4.33.

a) The capacitance of the surface mount capacitor shall be measured as specified in 4.7 and in the relevant sectional specification.
b) The capacitor shall be subjected to IEC 60068-2-21, Test Ue, using the conditions as prescribed in the relevant specification for the deflection D and the number of bends.
c) The capacitance of the surface mount capacitors shall be measured as specified in a) with the board in the bent position. The change of capacitance shall not exceed the limits prescribed in the relevant specification.

4.35.2 Recovery

The printed board shall be allowed to recover from the bent position and then removed from the test jig.

4.35.3 Final inspection and requirements

The surface mount capacitors shall be visually examined, and there shall be no visible damage.

4.36 Dielectric absorption

4.36.1 Test procedure

The capacitor under test shall be placed in a screened enclosure to reduce the effect of electric fields.

For the measurement of the voltage an electrometer or other suitable instrument having an input resistance of minimum 10 000 MΩ shall be used.

The resistance of any jigs, switches, etc. used shall not affect the input resistance of the measuring system.

The capacitor shall then be charged at the d.c. voltage rating for 60 min ± 1 min. The initial surge current shall not exceed 50 mA.

At the end of this period the capacitor shall be disconnected from the power source and shall be discharged through a 5 Ω ± 5 % resistor for 10 s ± 1 s, unless the specified du/dt value is exceeded.

The discharge resistor shall be disconnected from the capacitor at the end of the 10 s discharge period. The voltage remaining or regained on the capacitor (recovery voltage) shall be measured.

NOTE The recovery voltage is the maximum voltage occurring across the capacitor terminations within a 15 min period.

The dielectric absorption shall be calculated from the following formula:

$$DA = \frac{U_1}{U_2} \times 100 \times \frac{C_X + C_0}{C_X}$$

where

DA is the per cent dielectric absorption;

U_1 is the recovery voltage;

U_2 is the charging voltage;

C_X is the capacitance of capacitor under test;

C_0 is the input capacitance of measuring system.

If C_0 is less than 10 % of C_X, the above formula can be simplified to:

$$DA = \frac{U_1}{U_2} \times 100$$

4.36.2 Requirement

The dielectric absorption calculated shall not exceed the limit specified in the detail specification.

4.37 Damp heat, steady state, accelerated

NOTE This test is also known as humidity load test or (85/85)-test.

4.37.1 Initial measurements

The capacitors shall be measured as prescribed in the relevant specification.

4.37.2 Test methods

The capacitors shall be subjected to IEC 60068-2-67, Test Cy.

Preferred test durations: 168 h, 504 h or 1 000 h.

4.37.3 Test procedures

Test condition: rated voltage applied, unless otherwise prescribed in the relevant specification.

For metallized film capacitors this test should be carried out in accordance with Annex G, for multilayer ceramic capacitors in accordance with Annex H.

With the exception of electrolytic capacitors, within 15 min after removal from the test chamber, the voltage proof test of 4.6 shall be carried out at test point A only, using the rated voltage, unless otherwise specified in the detail specification.

4.37.4 Final inspection, measurements and requirements

After recovery (4 h to 24 h), the capacitors shall be visually examined. There shall be no visible damage. The measurements prescribed in the relevant specification shall then be made.

In case of testing metallized film capacitors, when specified in the blank detail specification, the permissible deviation of the average C-value of test group with and the test group without d.c. voltage shall be described in the relevant detail specification.

4.38 Passive flammability

4.38.1 Test procedure

The test shall be made according to IEC 60695-11-5.

The capacitor under test shall be held in the flame in the position which best promotes burning (if this position is not given in the detail specification it shall be evaluated by pre-testing). Each specimen shall be exposed only once to the flame.

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

For time of exposure to flame and burning time, see Table 7. If applicable, the detail specification shall specify the category of passive flammability.

4.38.2 Final inspection, measurements and requirements

The burning time of any specimen shall not exceed the time specified in Table 7.

Burning droplets or glowing parts falling down shall not ignite the tissue paper.

Table 7 – Severities and requirements

Category of flammability	Severities Flame exposure time, in seconds, for capacitor volume ranges				Maximum burning time s
	Volume ≤250 mm^3	Volume >250 mm^3 ≤ 500 mm^3	Volume >500 mm^3 ≤ 1 750 mm^3	Volume >1 750 mm^3	
A	15	30	60	120	3
B	10	20	30	60	10
C	5	10	20	30	30

4.39 High surge current test

4.39.1 Initial measurements

Not required.

4.39.2 Test procedure

The test shall be carried out at a temperature of (23 ± 3) °C.

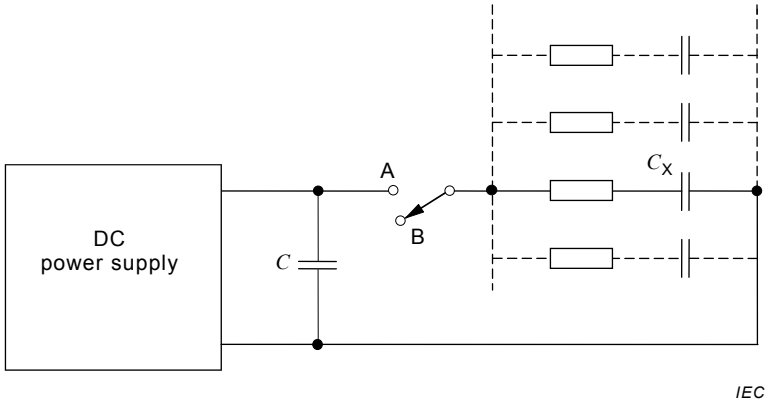
The test circuit is shown in Figure 17. The switch may be mechanical or electronic but is preferably electronic. With the switch in position A, the capacitor under test is charged for 1 s from a low-impedance electrolytic capacitor of capacitance at least 20 000 μF to the rated voltage of the capacitor under test (U_R ± 2 %) from a regulated power supply capable of delivering 10 A. The impedance of the circuit through which the capacitor under test is charged shall meet the requirements of 4.39.3. After 1 s charging time the capacitor under test shall be discharged for 1 s with the switch in position B through a circuit whose resistance is greater than 0,05 Ω, but less than 0,2 Ω.

The voltage across the capacitor under test shall be monitored. Four further chargings and dischargings of the capacitor under test shall be carried out under the same conditions.

Capacitors may be tested in parallel provided that

a) their total capacitance is less than 2 % of the capacitance of the reservoir capacitor, and
b) all the conditions specified above are met for each capacitor under test.

The fuse may be a wire fuse designed to blow between 0,5 A and 2,0 A or an electronic circuit designed to trip in the same current range.



Key

C_X capacitor under test

C low-impedance electrolytic capacitor of capacitance at least 20 000 μF

A, B switching positions

Figure 17 – High surge current test

4.39.3 Requirements for the charging circuit

The test procedure of 4.39.2 shall be carried out with a capacitor of 47 μF ± 10 %, 35 V in the test position, or in every one of the test positions if provision is made for testing capacitors in parallel. The monitoring of the voltage across the capacitor under test shall demonstrate that the peak voltage across the capacitor during charging is $U_R \, ^{+5}_{-2}$ %, and that 90 % of the measured peak voltage is achieved within 60 μs from the time of closure of the switch and without unwanted transients due to switch bounce or circuit inductance. Where there is provision for testing capacitors in parallel, this requirement shall be verified for each capacitor under test.

It is unlikely that this requirement will be met unless the d.c. resistance of the charging circuit including wiring, fuse, fixtures, and the series resistance of the tank capacitor is less than 0,5 Ω.

4.39.4 Nonconforming items

A capacitor shall be considered a nonconforming item if the fuse blows or the electronic circuit trips at any single charging or discharging of the capacitor.

4.40 Voltage transient overload (for aluminium electrolytic capacitors with non-solid electrolyte)

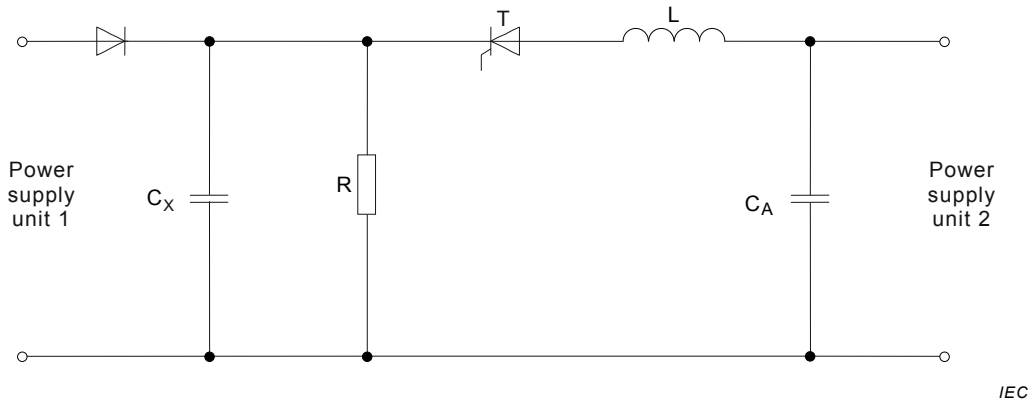
4.40.1 Initial measurement

The measurements prescribed in the detail specification shall be made.

4.40.2 Test procedure

The capacitor(s) shall then be conditioned at the test temperature by having U_R ± 1 % applied from a regulated power supply. At the end of this period, the test may commence but not later than 48 h after conditioning.

An example of a test circuit is shown in Figure 18.



Key

C_X capacitor under test

C_A bank capacitor to give a maximum charge time

R resistor to give a maximum charge time

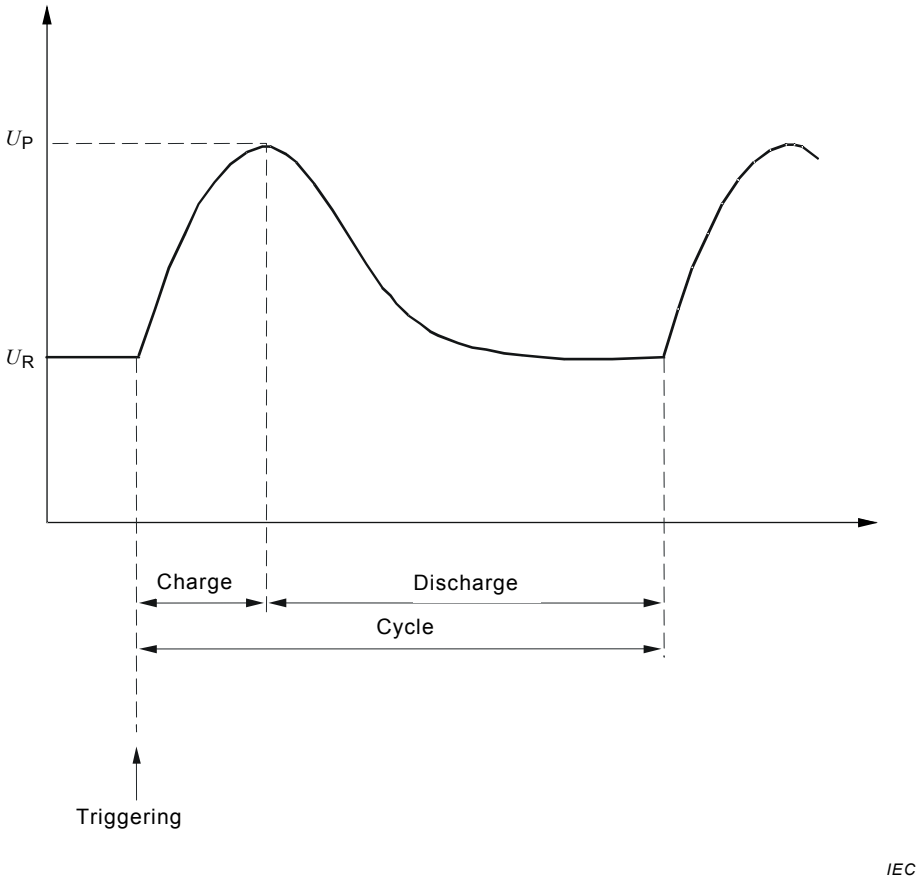
L inductor to give a maximum charge time

T thyristor

Figure 18 – Voltage transient overload test circuit

The capacitor under test C_X is charged from the power supply unit 1, and the auxiliary capacitor bank C_A is charged to a voltage higher than the test voltage U_P from the power supply unit 2. On triggering the thyristor T, the capacitor bank C_A is discharged through the inductor L charging the test capacitor C_X to U_P. On turning the thyristor off, the test capacitor C_X is discharged through the resistor R from U_P down to U_R.

The voltage waveform across the capacitor under test shall be approximately as shown in Figure 19.



Key

U_P transient peak voltage

U_R rated voltage

Figure 19 – Voltage waveform

4.40.3 Final inspection, measurements and requirements

The measurements specified in the relevant specification shall be made.

4.40.4 Conditions to be prescribed in the relevant specification

The relevant specification shall prescribe:

a) the duration of the conditioning period;
b) the value of the transient peak voltage U_P;
c) the value of C_A, L and R to give a maximum charge time of 15 ms;
d) the duration of each test cycle;
e) the number of test cycles;
f) the temperature if different from standard atmospheric conditions of testing.

4.41 Whisker growth test

4.41.1 General

If prescribed in the relevant specification, the whisker test shall be based on the recommendations of IEC 60068-2-82.

The relevant specification shall prescribe a suitable fixing jig for the support of the specimen during this test.

4.41.2 Preparation of specimen

The preparation of specimen shall be according IEC 60068-2-82:2007, Clause 5.

Capacitors intended for soldering shall receive a preconditioning by heat treatment according to IEC 60068-2-82:2007, 5.5.

Capacitors with leads shall receive a preconditioning by leads forming according to IEC 60068-2-82:2007, 5.6.

4.41.3 Initial measurement

The appearance of capacitors shall be examined according to IEC 60068-2-82:2007, 7.2.

4.41.4 Test procedures

The ambient test, the damp heat test and the temperature cycling test shall be applied according to the prescriptions in IEC 60068-2-82:2007, Clause 6.

4.41.5 Test severities

The severities of IEC 60068-2-82:2007, Table 6 according to the component's material composition shall be applied.

The following discrimination shall be applied to the selection of the severity of the temperature cycling test:

a) the severity N, –55 °C / 125 °C shall be applied for capacitors with LCT = –55 °C or below and UCT = 125 °C or above,
b) the severity K, –40 °C / 85 °C shall be applied for capacitors with LCT above –55 °C and/or UCT below 125 °C.

4.41.6 Final inspection, measurements and requirements

The capacitors shall be examined for appearance according to IEC 60068-2-82:2007, Annex A.

The whisker shall not exceed the limit prescribed in the detail specification.

Annex A
(informative)

Interpretation of sampling plans and procedures as described in IEC 60410 for use within quality assessment systems

When using IEC 60410 for inspection by attributes, the interpretations of the clauses and subclauses of IEC 60410, as indicated below, apply for the purpose of this standard.

1 The responsible authority is the national authorized institution implementing the basic rules and rules of procedure.

1.5 The unit of product is the electronic component defined in a detail specification.

2 Only the following definitions from this clause are required:

– a “defect” is any nonconformance of the unit of product to specified requirements;

– a “defective” is a unit of product which contains one or more nonconformances.

3.1 The extent of nonconformance of a product shall be expressed in terms of per cent defective.

3.3 Not applicable.

4.5 The responsible authority is the IEC technical committee drafting the blank detail specification which forms part of the generic or sectional specification.

5.4 The responsible authority is the designated management representative (DMR), acting in accordance with the procedures prescribed in the document describing the inspection department of the approved manufacturer, and approved by the Certification Body (CB).

6.2 The responsible authority is the DMR.

6.3 Not applicable.

6.4 The responsible authority is the DMR.

8.1 Normal inspection shall always be used at the start of inspection.

8.3.3 d) The responsible authority is the DMR.

8.4 The responsible authority is the national supervising inspectorate.

9.2 The responsible authority is the IEC technical committee drafting the blank detail specification which forms part of the generic or sectional specification.

9.4 (Fourth sentence only) Not applicable.
(Fifth sentence only) The responsible authority is the DMR.

10.2 Not applicable.

Annex B
(informative)

Rules for the preparation of detail specifications for capacitors and resistors for electronic equipment for use within quality assessment systems

B.1 Drafting

The drafting of a complete detail specification, if required, shall begin only when all the following conditions have been met.

a) The generic specification has been approved.
b) The sectional specification, when appropriate, has been circulated for approval as an Final Draft International Standard (FDIS).
c) The associated blank detail specification has been circulated for approval as an FDIS.
d) There is evidence that at least three national committees have formally approved, as their own national standard, specifications covering a component of closely similar performance.

When a national committee formally asserts that substantial or significant use is made within its country of a part described by some other national standard, this assertion may count towards the foregoing requirement.

B.2 Reference standard

Detail specifications shall use the standard of preferred values, ratings and characteristics and severities for environmental tests, etc., which are given in the appropriate generic or sectional specifications.

B.3 Circulation

The detail specification should not be circulated as an FDIS until the sectional and blank detail specifications have been approved for publication.

Annex C
(informative)

Layout of the first page of a PCP/CQC specification

Manufacturer's name

Location

Capability approval number PCP/CQC specification number

Issue

Capability manual reference number Date

Description of PCP/CQC

Purpose of PCP/CQC

Drawing reference

Part identity

Annex D
(informative)

Requirements for capability approval test report

D.1 General

Capability approval is decribed in Q.1.1 b).

The test report shall include the information given in Clauses D.2, D.3 and D.4.

D.2 Requirements

The test report shall be dated and include the following general information:

– manufacturer’s name and address;
– place of manufacture, if different from above;
– generic and sectional specification number, issue and amendment date;
– the issue number and date of the description of capability;
– reference to PCP/CQC specification;
– reference to the test programme for capability approval, as applicable;
– a list of test equipment used together with appropriate uncertainties of measurement.

D.3 Summary of test information (for each CQC)

The test report shall include the following summary of test information:

– tests;
– number of specimens tested;
– number of nonconforming items allowed;
– number of nonconforming items found.

D.4 Measurement record

A record of the results of the measurements is taken before and after the various mechanical, environmental, and endurance tests for which post-test limits or final measurements are specified.

Annex E
(informative)

Guide for pulse testing of capacitors

E.1 Overview

Existing testing methods covered by this standard are suitable for capacitors operating in circuits where the applied voltage is predominantly direct voltage. There are now an increasing number of applications in which the applied voltage is in the form of pulse with or without a reversal of polarity. These pulses may be continuous, intermittent, or random in occurrence.

This annex specifies the factors affecting pulse ratings and the way in which these ratings may be checked by appropriate endurance tests. The parameters of a pulse are defined. Different combinations of these parameters can give rise to different causes of failure as follows.

Type	Cause of failure	Test
Electrolytic	Surge voltage exceeded	Surge voltage
	Reverse voltage exceeded	Reverse voltage
	Overheating (I^2R)	Pulse or a.c.
Metallized types	Peak current	Charge/discharge (intermittent)
	du/dt	Pulse
	Overheating (I^2R)	Pulse or a.c.
	Ionization	a.c.
All other	du/dt	Pulse
	Overheating (I^2R)	Pulse or a.c.
	Excess peak voltage	Surge
	Ionization	a.c.

E.2 Typical capacitor pulse conditions

The figures listed below for typical applications show that test specifications requiring 100 000 or 1 million pulses correspond to operations of only 5 s to 50 s.

It is not possible to produce one circuit which will reproduce all of the required conditions.

It is likely, however, that circuits can be produced which will reproduce various groups of conditions. It does not appear possible at the present time to specify accelerated test conditions to simulate, for example, a five-year operation.

a) Examples for TV applications

- S-correction

Typical peak voltage:	25 V, 50 V, 180 V
Typical peak currents:	5 A to 15 A
du/dt:	about 5 V/μs
Frequency:	15 kHz to 20 kHz
Reactive power:	up to 250 var

- Line tuning

Typical peak voltage:	up to 1 500 V
Typical peak current:	5 A
du/dt:	180 V/μs

- Multiplier capacitors

Typical peak voltage:	10 kV d.c. with ripple
Typical peak current:	0,1 A
du/dt:	up to 1 000 V/μs

b) Examples for power electronics

Typical peak voltages:	60 V to 100 V
Typical peak currents:	40 A to 100 A
du/dt:	1 V/μs to 20 V/μs
Frequencies:	50 Hz to 20 kHz
Reactive power:	up to 500 var

c) Example for d.c.-d.c. convertors

Typical peak voltage:	30 V
Typical peak current:	6 A
du/dt:	600 V/μs
Frequency:	up to 20 kHz

d) Examples for switch-mode power supplies

Typical peak voltages:	15 V to 400 V
Typical peak currents:	2 A to 10 A
Frequencies:	100 Hz to 40 kHz

e) Examples for lasers and pulse light sources

Typical peak voltages:	1 kV to 3 kV
Typical peak current:	1 000 A
du/dt:	about 500 V/μs
Frequencies:	1 kHz to 5 kHz

E.3 Effect of inductance on pulse testing

Proposed pulse test methods are likely to consist of test circuits involving repetitive charge and discharge of capacitors in resistive circuits. This will result in conventional exponential current and voltage characteristics.

In many applications, however, inductive effects are of considerable importance and have a major influence on the suitability of the capacitor for the application.

These are particularly important at high values of du/dt. If the conditions for critical damping exist ($R^2 = 4 \times L/C$), the effect is a minor modification of the shape of the charge or discharge curve which will have little effect on the severity of the test.

If, however, $R^2 < 4 \times L/C$, there can be overshoot with or without damped oscillations.

These can result in overstress and increased power dissipation.

Annex F
(informative)

Guidance for the extension of endurance tests on fixed capacitors

F.1 Overview

The regular repetition of endurance tests under the quality conformance inspection within a quality system offers the opportunity to collect not only their results for the certified test records (CTR), but to accumulate them, wherever possible, for the evaluation of reliability data. As the usual duration of endurance tests on capacitors is 1 000 h or 2 000 h, interested parties may wish to extend these tests to evaluate the long-term behaviour of the components concerned and to improve the base for the reliability evaluation. In the following, guidance is given for the performance and evaluation of such extended endurance tests.

F.2 Guidelines

The following guidelines apply.

a) Test conditions should preferably be the same as for the standard endurance test. If, for any good reason, different test conditions are chosen, they should be clearly indicated.

b) For final measurements, the same characteristic should be measured as for the standard endurance test.

c) The preferred duration for such extended endurance tests is 8 000 h.

d) The extended test is for information only on long-term behaviour and reliability. The measured values are therefore noted for variable analyses or other reliability evaluation without being linked to the failure criteria as specified.

e) Intermediate measurements (between 2 000 h and 8 000 h) may be made.

f) If agreed between the parties concerned, the results of the test may be included in the certified test record (CTR) of released lots.

g) The “translation” of the results of accumulated tests into reliability data is normally the responsibility of the manufacturer. If somebody else wants to use these accumulated test results for his own reliability evaluation, an appropriate acceleration factor for the components concerned shall be taken into account.

Annex G
(normative)

Damp heat, steady state with voltage applied, for metallized film capacitors only

G.1 Overview

For corrosion sensitivity detection of the metallization of the dielectric film an additional test for damp heat, steady state test with applied voltage shall be carried out.

The deviation of the average capacitance values of the test group with, and the test group without voltage, indicates a possible corrosion of the metallization.

G.2 Test procedure

The damp heat, steady state test shall be carried out with applied a.c. or d.c. voltage, depending on the specified rated voltage of the capacitors.

The damp heat, steady state test with applied voltage shall be carried out on an additional test group. The specimens for both test groups with and without voltage can only be prepared by the manufacturer of the components, who will take care that the specimen for both groups are produced with identical materials and in identical production processes. The number of specimens for an additional test group with voltage is the same as the number for the test group without voltage.

Annex H
(normative)

Accelerated damp heat, steady state, for multilayer ceramic capacitors only

H.1 Mounting of capacitors

The capacitors shall be mounted so that each capacitor is connected in series with a resistor. Half of the capacitors shall be connected in series with resistors of 100 kΩ ± 10 % and half in series with resistors of 6,8 kΩ ± 10 %.

H.2 Initial measurement

The capacitors, mounted as in Clause H.1, shall be measured for insulation resistance with a voltage of 1,5 V ± 0,1 V applied across the capacitor and resistor in series.

The insulation resistance shall meet the requirements given in the relevant specification.

H.3 Test procedure

The capacitors with associated resistors shall be subjected to conditioning at (85 ± 2) °C, (85 ± 3) % RH for a duration to be specified in the relevant specification. Those capacitors connected to 100 kΩ resistors shall have a voltage of (1,5 ± 0,1) V applied, and those connected to 6,8 kΩ resistors shall have (50 ± 0,1) V or U_R applied, whichever is the lower. In both cases the voltage shall be applied across the capacitor/resistor combination.

Care shall be taken to avoid condensation of water on to the capacitors or substrates. Condensation may happen if the door is opened during the test before the humidity is lowered.

H.4 Recovery

The applied voltage shall be disconnected and the capacitors and resistors shall be removed from the test chamber and allowed to recover for 4 h to 24 h in standard atmospheric conditions for testing.

H.5 Final inspection, measurements and requirements

The capacitors, mounted as in accordance with Clause H.1, shall be measured for insulation resistance as in Clause H.2 above.

The insulation resistance shall be greater than 0,1 times the initial limit.

Annex Q
(informative)

Quality assessment procedures

Q.1 General

Q.1.1 Scope of this annex

This generic specification and related sectional and detail specifications can be used for the purpose of a full quality assessment system. The following types of approval are provided.

a) Qualification Approval (QA) is applicable to an identified component or range of components manufactured to similar design and production processes, for which a detail specification exists. Such a detail specification shall be based on this generic specification and a relevant sectional specification and shall give provisions for a QA.

   QA is granted to a manufacturer according to the provisions of Clause Q.2 when it has been established that the components meet the requirements of the detail specification.

   The test schedules prescribed in the detail specification for the initial product qualification approval and for the product quality conformance inspections apply directly to the component or range to be qualified.

b) Capability Approval (CA) is applicable to an identified component manufacturing process and set of design rules for which an applicable sectional specification exists. Such a sectional specification shall be based on this generic specification and shall give provisions for a CA.

   CA is granted to a manufacturer according to the provisions of Clause Q.3 when it has been established that his capability for manufacturing processes and quality control methods covering a specific component technology meet the requirements of the relevant specifications.

   There are different detail specifications used under CA. At least one detail specification is released for the Capability Qualifying Components (CQC), identifying the component's purpose and prescribing the relevant tests and requirements. Other detail specifications are released for the deliverable components and thus may cover standard catalogue components or customer specific components.

c) Technology Approval (TA) is appropriate when the complete technological process (design, process realization, product manufacture, test and shipment) covers the qualification aspects common to all components determined by the technology. It incorporates the most recent principles and techniques in quality management and provides for the use of statistical methods and tools, continuous improvement and procedural flexibility.

   TA is applicable to an identified electronic component manufacturing activity for which a Technology Approval Schedule (TAS) exists.

   TA is granted to a manufacturer according to the provisions of Clause Q.4, when it has been demonstrated that the quality management system established for his electronic component manufacturing activity complies with the contents of his/her Technology Approval Declaration Document (TADD), and meets the requirements of the TAS.

   The identification of an electronic component manufacturing activity shall be based on component(s) or range(s) of components manufactured to similar design and production processes, for which detail specification(s) exist(s). Such detail specification(s) shall be based on this generic specification and relevant sectional specification(s) and shall give relevant provisions for a technology approval. Such applied detail specifications are to be referenced in the TA.

A prerequisite for obtaining any of these approvals is that a manufacturer has obtained the approval of manufacturer in accordance with the provisions of the relevant certification body.

Q.1.2 Quality assessment definitions

Q.1.2.1 Primary stage of manufacture

The primary stage of manufacture shall be specified in the sectional specification.

Examples of the primary stage of manufacture are:

- For film capacitors:
  the winding of the capacitor element or the equivalent operation.
- For ceramic capacitors:
  the first common firing of the dielectric-electrode assembly.
- For electrolytic capacitors:
  the capacitor manufacturer's evaluation of the formed anode foil.

Q.1.2.2 Structurally similar components

The grouping of structurally similar components for the initial product qualification approval testing or for the product quality conformance testing under QA, CA or TA shall be prescribed in the relevant sectional specification.

Q.1.2.3 Assessment level

An assessment level prescribes the severity of the test schedules, the sampling plans and the number of permissible non-conforming items in each test group. Assessment levels EZ and DZ meet the requirements of the zero defect approach and align the assessment procedures and levels with the current industry practices, e.g. by setting the number of permitted non-conformities (acceptance number) to zero. The sectional specifications shall prescribe the requirements to the test schedules for use in all related detail specifications.

NOTE 1 A variety of assessment levels existed historically, e.g. with different numbers of permissible non-conformities per test. Only the assessment levels EZ and DZ are used in recent specifications.

The sampling plans and inspection levels for assessment levels EZ and DZ shall be selected from those given in IEC 61193-2, except for those elements of the test schedule which are based on fixed sample sizes, irrespective of the size of the lot being inspected.

NOTE 2 The assessment of a quality level close or equal to zero defects by sampling only would lead to an unreasonable increase of inspection efforts. Hence, zero acceptance number sampling plans can only apply to the inspection of products that are manufactured under suitable process control with the target of a zero-defect quality level before sampling inspection.

Q.1.2.4 Failure rate level determination (if applied)

The determination of failure rate level and certification shall be described in the relevant specification.

Q.1.3 Rework

Rework is the rectification of a processing error by means not differing from those used in the current process, or by an explicitly permitted rework process prior to release of the component.

Rework shall not be carried out if prohibited by the relevant sectional or detail specification.

Applicable rework procedures shall be permitted by the relevant sectional or detail specification and shall be fully described in the relevant documentation produced by the manufacturer. All rework shall be carried out under supervision of the Designated Management Representative (DMR) prior to the formation of the inspection lot offered for inspection to the requirements of the detail specification.

Q.1.4 Alternative test methods

The test and measurement methods given by the relevant specification are intended to unify test and measurement procedures. They are not necessarily the only methods which can be used except when specifically designated as referee or reference methods.

An approved manufacturer shall demonstrate to the Certification Body (CB) that any alternative method he uses will give results equivalent to those obtained by the specified method.

In case of dispute, the specified methods take precedence over any alternative method.

Q.1.5 Certified test records of released lots

When certified test records are prescribed in the relevant specification and are requested by a customer, the following information shall be given as a minimum.

a) Attributes information (that is the number of components tested and the number of non-conforming components) for tests in the sub-groups covered by periodic inspection without reference to the parameter for which rejection was made.
b) Variables information (that is average and range for the change in capacitance and number of tested components) for periodic tests specified in the relevant sectional specification.

NOTE Under CA a certified test record refers only to tests carried out on capability qualifying components.

Q.1.6 Unchecked parameters

Only those parameters of a component which have been specified in the detail specification and which were subject to testing shall be assumed to be within the specified limits. It cannot be assumed that any unspecified parameter will remain unchanged from one component to another.

A new, more extensive specification shall be used if control of any additional parameter is required. Then the additional test method shall be fully described with specification of sampling plans, inspection levels and requirements and applied in a relevant test schedule.

Q.1.7 Delayed delivery

Components are considered to meet the stated requirements for a period of two years after manufacture and lot release when stored under appropriate conditions, unless otherwise specified in the relevant specification.

Components held for a period exceeding that retention period shall prior to delivery be re-examined for solderability and for electrical characteristics as prescribed in the relevant specification. The sampling and procedure applied for re-examination shall be approved by the Certification Body (CB).

Components are qualified for another retention period, if all relevant requirements were met in the re-examination.

Q.1.8 Repair

Repair consists of rendering an approved component usable which has been damaged or has become defective after its release.

Components which have been repaired shall not be released under any specified quality assessment system.

Q.1.9 Registration of approvals

Approvals shall be based on a published detail specification complying with this generic specification and a relevant sectional specification.

The achieved approvals shall be entered in a relevant and published Register of Approvals, e.g. in the approvals section “online certificates” of the website www.iecq.org. Such entries shall contain all necessary details on the approval, including the applied specifications and the scope of the approval, e.g. designation, variant(s) and range(s) of the approved component(s).

Q.1.10 Manufacture outside the geographical limits

See the requirements of the specified quality assessment system (if any).

Q.2 Qualification approval (QA) procedures

Q.2.1 Eligibility for qualification approval

A qualification approval may be granted to a manufacturer holding a manufacturer's approval.

A component is eligible for QA if the manufacturing process, including the prescribed primary stage of manufacture, is carried out under direct supervision of the relevant Designated Management Representative (DMR).

Q.2.2 Application for qualification approval

The manufacturer shall comply with the specified quality assessment system (if any).

Q.2.3 Subcontracting

The relevant specification may restrict subcontracting according to the specified quality assessment system (if any).

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed, it shall be in accordance with the specified quality assessment system (if any).

Q.2.4 Test procedure for the initial product qualification approval

The detail specification shall prescribe the test schedule and the requirements for the initial product qualification approval testing.

The sampling and formation of inspection lots shall be prescribed in the sectional specification or in the detail specification. The sampling plan for the initial product qualification approval testing is based on the fixed sample size procedure, with the number of permissible non-conforming specimen set to zero (e.g. assessment level EZ).

The specimen for an inspection lot shall be collected at random over a short time within an inspection period, not including any major change of the manufacturing process.

Q.2.5 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with the specified quality assessment system (if any) have been completed satisfactorily.

Q.2.6 Maintenance of qualification approval

A QA shall be maintained by regular quality conformance inspections in order to demonstrate the compliance with the requirements for quality conformance prescribed in the detail specification.

Q.2.7 Quality conformance inspection

The test schedule and the requirements for the product quality conformance inspection shall be prescribed in the detail specification.

The sampling and formation of inspection lots shall be prescribed in the sectional specification or in the detail specification. The sampling plans and inspection levels shall be selected from those given in IEC 61193-2, for the part of the product quality conformance inspection schedule based on variable sample sizes, as used for the lot-by-lot testing. The sampling plan for the periodic product quality conformance inspection testing is based on the fixed sample size procedure. The number of permissible nonconforming specimen for each test group of both test schedules is set to zero (e.g. assessment level EZ).

The specimen for an inspection lot shall be collected at random over a short time within an inspection period, not including any major change of the manufacturing process.

Utilisation of the switching rule for reduced inspection in Group C of the test schedule is permitted in all subgroups except endurance, unless otherwise prescribed in the relevant specification.

Q.3 Capability approval (CA) procedures

Q.3.1 General

Capability Approval covers a manufacturing process and quality control methods (including design aspects as applicable) for a specific component technology with clearly defined scope and limits of the employed manufacturing capability.

The capability shall be demonstrated on Capability Qualifying Components (CQC), which serve as specimen for initial qualification testing and for subsequent quality conformance inspections. There shall be a detail specification for a CQC, based on this generic specification and on a sectional specification, giving the provisions for a CA.

A detailed Process Control Plan (PCP) shall be used for inspections to be carried out during the manufacturing process applied to the manufacturing of components for release.

There shall be specific detail specifications for standard catalogue components and for customer specific components to be released under capability approval. They shall be based on this generic specification and on the same sectional specification supporting the detail specification for the CQC.

Q.3.2 Eligibility for capability approval

The manufacturer shall comply with the requirements of the specified quality assessment system (if any).

A component manufacturer is eligible for CA if the manufacturing process, including the prescribed primary stage of manufacture, is carried out under direct supervision of the relevant Designated Management Representative (DMR).

Q.3.3 Application for capability approval

The manufacturer shall comply with the requirements of the specified quality assessment system (if any), and with the requirements of the relevant sectional specification.

Q.3.4 Subcontracting

The relevant specification may restrict subcontracting according to the rules of the specified quality assessment system (if any).

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed, it shall be in accordance with the specified quality assessment system (if any).

Q.3.5 Description of the capability

The manufacturer shall describe the capability relevant to the manufacturing technology and range of products involved in a Capability Manual (CM), which shall meet the requirements of the specified quality assessment system (if any). The CM shall state the limits of the covered technology, and design rules, if applicable.

The CM may be subject to confidentiality, hence the manufacturer shall provide an abstract of the description of capability suitable for publication.

Q.3.6 Demonstration and verification of capability

The verification of the claimed capability shall demonstrate compliance with the contents of the CM and utilize Capability Qualifying Components (CQC) and the Process Control Plan (PCP), as required by the specified quality assessment system (if any).

The CQCs shall be used to demonstrate the limits of capability and compliance with the relevant detail specification.

Q.3.7 Granting of capability approval

Capability approval shall be granted when the procedures in accordance with the specified quality assessment system (if any) have been completed satisfactorily and the requirements of the relevant sectional specification have been met.

Q.3.8 Maintenance of capability approval

A Capability Approval shall be maintained according to the specified quality assessment system (if any) and to the respective descriptions of the CM by regular quality conformance inspections on the CQCs in order to demonstrate the compliance with the requirements for quality conformance prescribed in the relevant detail specification.

Q.3.9 Quality conformance inspection

Quality conformance inspections shall be executed according to the provisions of the specified quality assessment system (if any) and to the respective descriptions of the CM.

The test schedule and the requirements for the quality conformance inspection shall be prescribed in the relevant detail specification(s) for deliverable components, e.g. the specific detail specifications for standard catalogue components or for customer specific components.

The sampling and formation of inspection lots shall be prescribed in the sectional specification or in the detail specification. The sampling plans and inspection levels shall be selected from those given in IEC 61193-2, except for those elements of the test schedule which are based on fixed sample sizes.

The specimen for an inspection lot shall be collected at random over a short time within an inspection period, not including any major change of the manufacturing process.

Q.4 Technology approval (TA) procedure

Q.4.1 General

Technology Approval is a method of approving a complete technological process covering the approval aspects common to all products as determined by the technology under consideration. It extends the existing suite of approval concepts (QA and CA) by adding the following principles as mandatory aspects:

a) a formal system for quality management, actively involving all employees in the commitment to quality;

b) use of in-process control methods, for example, SPC, to be defined in a Technology Approval Schedule (TAS);

c) a strategy for continuous quality improvement;

d) monitoring the overall technologies and operations associated with the design and manufacturing processes as well as the components themselves;

e) procedural flexibility due to the underlying quality assurance management system and market sector requirements;

f) acceptance of a manufacturer's operational documentation to provide means for rapid approval or extension of approval.

Q.4.2 Eligibility for technology approval

A TA may be granted to a manufacturer holding an Approval of Manufacturer to the specified quality assessment system (if any).

Prerequisite to a TA is a Technology Approval Schedule (TAS) covering the entire scope of technology for which approval is intended, written according to the requirements of the specified quality assessment system (if any).

Q.4.3 Application of technology approval

The procedure and requirements for an application for TA are given in the specified quality assessment system (if any).

Q.4.4 Subcontracting

The TAS or the relevant specification may restrict subcontracting according to the rules of the specified quality assessment system (if any).

Q.4.5 Description of technology

The manufacturer shall describe the implementation of the TAS in his organisation in a Technology Approval Declaration Document (TADD) which shall meet the requirements of the specified quality assessment system (if any). The TADD shall describe the relevant scope of technology and relate to, but not exceed the range of activities covered by the TAS.

Q.4.6 Demonstration and verification of the technology

For verification of the operational and technological processes, the manufacturer shall demonstrate compliance with the contents of the TADD, as required in the specified quality assessment system (if any).

For manufacturing verification, characterisation and evaluation of process performance shall be performed on components, for which a detail specification exists. Such detail specification

shall be based on this generic specification and a sectional specification and shall give provisions for a TA.

Q.4.7 Granting of technology approval

TA shall be granted by the Certification Body (CB) when the requirements of the specified quality assessment system (if any) have been met.

Q.4.8 Maintenance of technology approval

A TA shall be maintained according to the provisions of the specified quality assessment system (if any).

Q.4.9 Quality conformance inspection

The quality conformance inspection shall be carried out in accordance with the relevant TAS.

The quality conformance inspection of the manufacturing shall be performed on components for which a detail specification has been registered in the TADD. The test schedule and the requirements for the quality conformance inspection shall be prescribed in the detail specification.

The sampling and formation of inspection lots shall be prescribed in the sectional specification or in the detail specification. The sampling plans and inspection levels shall be selected from those given in IEC 61193-2, except for those elements of the test schedule which are based on fixed sample sizes.

The specimen for an inspection lot shall be collected at random over a short time within an inspection period, not including any major change of the manufacturing process.

Utilisation of the switching rule for reduced inspection in Group C of the test schedule is permitted in all subgroups except endurance, unless otherwise prescribed in the relevant specification.

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