भारतीय मानक

Indian Standard

IS 2993 (Part 1) : 2024
IEC 60252-1 : 2010 +
AMD 1 : 2013

(*Superseding IS 1709 : 1984*)

ए.सी.मोटर संधारित्र

भाग 1 सामान्य — निष्पादन, परीक्षण और रेटिंग — सुरक्षा अपेक्षाएँ — स्थापना और संचालन के लिए दिशानिर्देश

(तीसरा पुनरीक्षण)

a.c. Motor Capacitors

Part 1 General — Performance, Testing and Rating — Safety Requirements — Guidance for Installation and Operation

(Third Revision)

ICS 31.060.30; 31.060.70

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Power Capacitors Sectional Committee, ETD 29

NATIONAL FOREWORD

This Indian Standard (Part 1) (Third Revision) which is identical to IEC 60252-1 : 2010 + AMD 1 : 2013 'a.c. Motor capacitors — Part 1: General — Performance, testing and rating — Safety requirements — Guidance for installation and operation' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Power Capacitors Sectional Committee and approval of the Electrotechnical Division Council.

This revision of IS 2993 has been taken to harmonize it with the latest version of IEC 60252.

IS 2293 Part 1 covers fan drive application which was earlier covered in IS 1709: 1984. With the publication of this standard, IS 1709, would be withdrawn

This standard is published in two parts. Other part in this series is:

Part 2 Motor start capacitors

Part 1 Deals with motor capacitors intended for connection to windings of asynchronous motors supplied from a single-phase system having a frequency up to and including 100 Hz and to capacitors to be connected to three-phase asynchronous motors so that these motors may be supplied from a single-phase system; and

Part 2 Deals with motor start capacitors intended for connection to windings of asynchronous motors supplied from a single-phase system having the frequency of the mains.

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

a) The definition of "segmented capacitors" has been added in **3.6**;
b) The definition of "classes of operation" has been clarified, with the addition of the concept of "probable life" with reference to statistics, in **3.9**;
c) The following wording "Operation above the rated voltage will reduce the life expectancy of the capacitor" has been introduced in **6.1**;
d) Some clarifications have been added to Clause 8, Marking, mainly for small capacitors.
e) Classes of safety protection has been redefined **3.22**;
f) Destruction test has been redefined **5.16**; and
g) New type test 'Resistance to heat, fire and tracking' added **5.17**.

The text of the IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and
b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to International Standards for which Indian Standards also exists. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60062 Marking codes for resistors and capacitors	IS 8186 : 2020/IEC 60062 : 2016 Marking codes for resistors and capacitors (*first revision*)	Identical
IEC 60068 (all parts) Environmental testing	IS/IEC 60068 (all parts) Environmental testing	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60068-2-6 Environmental testing — Part 2-6: Tests — Test Fc: Vibration (sinusoidal)	IS/IEC 60068-2-6 : 2007 Environmental testing: Part 2 Tests, Section 6 Test Fc: Vibration (sinusoidal)	Identical
IEC 60068-2-20 Environmental testing — Part 2-20: Tests — Test T: Test methods for solderability and resistance to soldering heat of devices with leads	IS/IEC 60068-2-20 : 2021 Environmental testing: Part 2 Tests Section 20 Tests Ta and Tb: Test methods for solderability and resistance to soldering heat of devices with leads	Identical
IEC 60068-2-21 Environmental testing — Part 2- 21: Tests — Test U: Robustness of terminations and integral mounting devices	IS/IEC 60068-2-21: 2021 Environmental testing: Part 2- 21: Tests — Test U: Robustness of terminations and integral mounting devices	Identical
IEC 60068-2-78 Environmental testing — Part 2-78: Tests — Test Cab: Damp heat, steady state	IS 9000 (Part 4) : 2020/ IEC 60068- 2-78 : 2012 Environmental testing: Part 4 Tests — Test cab: Damp heat, steady state (*second revision*)	Identical
IEC 60112 Method for the determination of the proof and the comparative tracking indices of solid insulating materials	IS 2824 : 2007/IEC 60112 : 2003 Method for the determination of the proof and the comparative tracking indices of solid insulating materials (*second revision*)	Identical
IEC 60309-1 Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements	IS/IEC 60309-1 : 2002 Plugs, socket — Outlets and couplers for industrial purposes: Part 1 General requirements (*first revision*)	Identical
IEC 60529 : 2001 Degrees of protection provided by enclosures (IP Code)	IS/IEC 60529 : 2001 Degrees of protection provided by enclosures (IP code)	Identical
IEC 60695-2-10 Fire hazard testing — Part 2-10: Glowing/ hot-wire based test methods — Glow-wire apparatus and common test procedure	IS/IEC 60695-2-10 : 2021, Fire hazard testing Part 2: Glowing/ hot-wire based test methods, Section 10 Glow-wire apparatus and common test procedure	Identical
IEC 60695-2-11 Fire hazard testing — Part 2-11: Glowing/ hot-wire based test methods — Glowwire flammability test method for end products	IS/IEC 60695-2-11 : 2021 Fire hazard testing: Part 2 Glowing/ hot-wire based test methods, Section 11 Glowwire flammability test method forend products (GWEPT) (*first revision*)	Identical

The Committee has reviewed the provisions of the following International Standards referred in this adopted standard and decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 4046 : 2002	Paper, board, pulps and related terms — Vocabulary

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the International Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision)*’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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CONTENTS

Indian Standard

a.c. MOTOR CAPACITORS

PART 1 GENERAL — PERFORMANCE, TESTING AND RATING — SAFETY REQUIREMENTS —GUIDANCE FOR INSTALLATION AND OPERATION

(Third Revision)

1 Scope and object

This part of IEC 60252 applies to motor capacitors intended for connection to windings of asynchronous motors supplied from a single-phase system having a frequency up to and including 100 Hz, and to capacitors to be connected to three-phase asynchronous motors so that these motors may be supplied from a single-phase system.

This standard covers impregnated or unimpregnated capacitors having a dielectric of paper, plastic film, or a combination of both, either metallized or with metal-foil electrodes, with rated voltages up to and including 660 V.

Motor start capacitors are covered by IEC 60252-2.

NOTE The following are excluded from this standard:

– shunt capacitors of the self-healing type for a.c. power systems of up to and including 1 000 V nominal voltage (see IEC 60831-1);

– shunt capacitors of non-self-healing type for a.c. power systems of up to and including 1 000 V nominal voltage (see IEC 60931-1);

– shunt capacitors for a.c. power systems having a nominal voltage above 1 000 V (see IEC 60871-1);

– capacitors for induction heat-generating plants, operating at frequencies between 40 Hz and 24 000 Hz (see IEC 60110-1);

– series capacitors (see IEC 60143);

– coupling capacitors and capacitor dividers (see IEC 60358);

– capacitors to be used in power electronic circuits (see IEC 61071);

– small a.c. capacitors to be used for fluorescent and discharge lamps (see IEC 61048);

– capacitors for suppression of radio interference (IEC publication under consideration);

– capacitors intended to be used in various types of electrical equipment and thus considered as components;

– capacitors intended for use with d.c. voltage superimposed on a.c. voltage.

The object of this standard is

a) to formulate uniform rules regarding performance, testing and rating;

b) to formulate specific safety rules;

c) to provide a guidance for installation and operation.

2 Normative references

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

IEC 60062, *Marking codes for resistors and capacitors*

IEC 60068 (all parts), *Environmental testing*

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

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

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

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

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

IEC 60529:2001, *Degrees of protection provided by enclosures (IP Code)*

IEC 60695-2-10, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end products*

ISO 4046:2002, *Paper, board, pulps and related terms – Vocabulary*

3 Terms and definitions

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

3.1
motor running capacitor
a power capacitor which, when used in conjunction with an auxiliary winding of a motor, assists the motor to start and improves the torque under running conditions

NOTE The running capacitor is usually connected permanently to the motor winding and remains in circuit throughout the running period of the motor. During the starting period, if it is in parallel with the starting capacitor, it helps to start the motor.

3.2
motor starting capacitor
a power capacitor which provides a leading current to an auxiliary winding of a motor and which is switched out of circuit once the motor is running

3.3
metal foil capacitor
a capacitor, the electrodes of which consist of metal foils or strips separated by a dielectric

3.4
metallized capacitor
a capacitor, in which the electrodes consist of a metallic deposit on the dielectric

3.5
self-healing capacitor
a capacitor, the electrical properties of which, after local breakdown of the dielectric, are rapidly and essentially self-restored

3.6
segmented film capacitor
a metallised capacitor with a repeating pattern on the metallic deposit on at least one layer, designed to isolate sections of the capacitor in the event of localised faults occurring in the dielectric

3.7
discharge device of a capacitor
a device which may be incorporated in a capacitor, capable of reducing the voltage between the terminals effectively to zero, within a given time, after the capacitor has been disconnected from a network

3.8
continuous operation
operation with no time limit within the normal life of the capacitor

3.9
class of operation
the minimum probable total life for which the capacitor has been designed at rated duty, voltage, temperature and frequency

NOTE 1 Four classes have been foreseen

Class A – 30 000 h

Class B – 10 000 h

Class C – 3 000 h

Class D – 1 000 h

These classes of operation are intended to represent a probable failure rate not exceeding 3 % during the life of the product.

Failures considered are: short-circuits, interruptions, leakage of liquid, capacitance drifts exceeding 10 % out of the rated tolerance limits

A capacitor may have more than one class with corresponding voltages.

NOTE 2 Classes of operation have a statistical value (the “law of big numbers”): it is not possible to transfer automatically data coming from a limited quantity to a whole population or even to a batch of capacitors. The purchaser and the manufacturer should agree upon to confront the case of a true failure rate larger than 3 %.

3.10
minimum permissible capacitor operating temperature
minimum permissible temperature on the outside of the case at the moment of switching on the capacitor

3.11
maximum permissible capacitor operating temperature
t_C
maximum permissible temperature of the hottest area of the outside of the capacitor case during operation

3.12
rated voltage of a capacitor
U_N
r.m.s. value of the alternating voltage for which the capacitor has been designed

3.13
rated frequency of a capacitor
f_N
highest frequency for which the capacitor has been designed

3.14
rated capacitance of a capacitor
C_N
capacitance value for which the capacitor has been designed

3.15
rated current of a capacitor
I_N
r.m.s. value of the alternating current at the rated voltage and frequency for which the capacitor has been designed

3.16
rated output of a capacitor
Q_N
reactive power derived from the rated values of capacitance, frequency and voltage (or current)

3.17
capacitor losses
active power dissipated by a capacitor

NOTE Unless otherwise stated, the capacitor losses will be understood to include losses in fuses and discharge resistors forming an integral part of the capacitor.

3.18
tangent of loss angle (tan delta) of a capacitor
ratio between the equivalent series resistance and the capacitive reactance of a capacitor at specified sinusoidal alternating voltage and frequency

3.19
capacitive leakage current (only for capacitors with a metal case)
current flowing through a conductor connecting the metallic case to earth, when the capacitor is energized from an a.c. supply system with an earthed neutral

3.20
type of capacitor
capacitors are considered to be of the same type when of similar constructional form, the same constructional technology, same rated voltage, same climatic category and same kind of operation. Capacitors of the same type can differ only in rated capacitance and size. Minor differences between terminations and mounting devices are permitted

NOTE The same construction includes, for example, the same dielectric material, dielectric thickness and type of case (metal or plastic).

3.21
model of capacitor
capacitors are considered to be of the same model when they are of the same construction and have the same functional and dimensional characteristics within the tolerance limits and are consequently interchangeable

3.22
class of safety protection
degree of safety protection identified by one of four codes to be marked on the capacitor

3.22.1
(SO) class of safety protection
degree of safety protection indicating that the capacitor type has no specific failure protection

Note 1 to entry: Formerly referred to as P0.

3.22.2
(S1) class of safety protection
degree of safety protection indicating that the capacitor type may fail in the open-circuit or short-circuit mode and is protected against fire or shock hazard

Note 1 to entry: Compliance is verified by the test described in 5.16.3 and 5.16.5.

Note 2 to entry: Formerly referred to as P1.

3.22.3
(S2) class of safety protection
degree of safety protection indicating that the capacitor type has been designed to fail in the open-circuit mode only and is protected against fire or shock hazard

Note 1 to entry: Compliance is verified by the test described in 5.16.3 and 5.16.5.

Note 2 to entry: formerly referred to as P2.

3.22.4
(S3) class of safety protection
degree of safety protection indicating that the capacitor is of segmented film construction as defined in 3.6

Note 1 to entry: This capacitor type is required to fail with low residual capacitance (<1 % C_N) and has protection against fire and shock hazard. Compliance is verified by the test described in 5.16.4 and 5.16.6.

4 Service conditions

4.1 Normal service conditions

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

a) altitude: not exceeding 2 000 m;

b) residual voltage at energization: shall not exceed 10 % rated voltage (see 7.4, note);

c) pollution: capacitors included in the scope of this standard are designed for operation in lightly polluted atmospheres;

NOTE The IEC has not yet established a definition for "lightly polluted". When this definition is established by the IEC, it will be incorporated in this standard.

d) operating temperature: between –40 °C and +100 °C (see 3.10 and 3.11).

The preferred minimum and maximum permissible capacitor operating temperatures are as follows:

– minimum temperatures: –40 °C, –25 °C, –10 °C and 0 °C;

– maximum temperatures: 55 °C, 70 °C, 85 °C and 100 °C.

Capacitors shall be suitable for transport and storage at temperatures down to –25 °C, or the minimum operating temperature, whichever is the lower, without adverse effect on their quality;

e) damp heat severity: between 4 days and 56 days. The preferred severity is 21 days.

(The damp heat severity shall be selected from the values indicated by IEC 60068-2-78, i.e.: 4 days, 10 days, 21 days and 56 days.)

Capacitors are classified in climatic categories defined by the minimum and maximum permissible capacitor operating temperatures and damp heat severity; i.e. 10/70/21 indicates that the minimum and the maximum permissible capacitor operating temperatures are –10 °C and 70 °C and the damp heat severity is 21 days.

4.2 Preferred tolerances on capacitance

Preferred tolerances are as follows: ±5 %, ±10 % and ±15 %.

Asymmetric tolerances are permitted but no tolerance shall exceed 15 %.

5 Quality requirements and tests

5.1 Test requirements

5.1.1 General

This clause gives the test requirements for capacitors.

5.1.2 Test conditions

Unless otherwise specified for a particular test or measurement, the temperature of the capacitor dielectric shall be in the range +15 °C to +35 °C and shall be recorded.

If corrections are necessary, the reference temperature shall be +20 °C.

NOTE It may be assumed that the dielectric temperature is the same as the ambient temperature, provided that the capacitor has been left in an unenergized state at this ambient temperature for an adequate period, depending on the size of the capacitor.

5.2 Nature of tests

The tests specified are of two sorts:

a) type tests;

b) routine tests.

5.2.1 Type tests

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

Type tests are carried out by the manufacturer and/or the test authority if there is need for an approval.

These tests may be carried out under the supervision of a proper authority which will issue a certified record and/or type approval.

5.2.2 Routine tests

Routine tests shall be carried out by the manufacturer on every capacitor before delivery. If the purchaser so requests, he shall be supplied with a certificate stating that routine tests have been carried out.

5.3 Type tests

5.3.1 Test procedure

The samples of each model selected for the type tests shall be divided into groups, as indicated in Table 1.

Capacitors forming the sample shall have successfully passed the routine tests indicated in 5.4.1.

Each test group shall contain equal numbers of capacitors of the highest capacitance and the lowest capacitance in the range.

The manufacturer shall provide data on the ratio of capacitance per outer total surface area of the case of each capacitance value in the range.

The capacitor with the maximum capacitance per unit surface area shall also be tested if this ratio exceeds that of the maximum capacitance value in the range by 10 % or more.

Similarly, the capacitor with the minimum capacitance per unit area shall also be tested if the ratio is less than that of the minimum capacitance value in the range by 10 % or more.

"Area" denotes total outer surface area of the capacitor case with the exception of small protrusions, terminals and fixing studs.

5.3.2 Extent of qualification

5.3.2.1 A type test on a single model qualifies only the model tested. When the type test is performed on two models of the same type, and of different rated capacitance value, selected under the rules of 5.3.1, the qualification is valid for all models of the same type having rated capacitance between the two tested values.

5.3.2.2 The qualification tests carried out successfully on a capacitor model having a certain capacitance tolerance are valid also for capacitors of the same model but having a different capacitance tolerance of up to twice the limits of the declared tolerance. For example, ±5 % would cover up to ±10 %, and ±10 % would cover up to ±20 %. A smaller tolerance than the declared tolerance is not permitted. For example, a type approval for ±10 % would not cover ±5 %.

5.3.2.3 Occasionally, in current practice, capacitors are required with a capacitance tolerance that is not symmetrical with respect to the rated capacitance value.

When a type test is carried out successfully on a capacitor model having a symmetrical capacitance tolerance, the relevant qualification is valid also for capacitors of the same model having a non-symmetrical capacitance provided that the total range of non-symmetrical tolerance is

a) within the total range of capacitance allowed in 5.3.2.2,

   and

b) greater than, or equal to, that of the tested capacitor model. For example, qualification for ±5 would allow values such as $^{+10}_{-5}$ %, $^{+5}_{-10}$ %, $^{+8}_{-2}$ %, $^{+10}_{0}$ %, but not $^{+15}_{-5}$ %.

Table 1 – Type test schedule

Group	Tests	Subclause	Number of samples to be inspected (note 1)	Number of failures allowed in first test (note 2)	Number of failures allowed in retest
1	Visual examination Check markings Check of dimensions Mechanical tests *(excluding soldering)* Sealing tests *(if applicable)*	5.6 8 5.10 5.11 5.12	8 [4]	1 (note 3)	0
2	Endurance test	5.13	42 [21]	2 (note 4)	0
3	Soldering *(if applicable)* Damp heat test Voltage test between terminals Voltage test between terminals and case	5.11.2 5.14 5.7 5.8	12 [6]	1 (note 3)	0
4	Self-healing test *(if applicable)*	5.15	20 [10]	1 (note 3)	0
5	Destruction test *(if marked on the capacitor)*	5.16	20 [10] 10 [5]	1 (note 5)	0
6	Resistance to heat, fire and tracking (not applicable to capacitors with lead terminations)	5.17	3 (Terminal housing only) (see note 6)	0	0

NOTE 1 The number of samples specified allows for retest if required. The number in square brackets indicates the actual number required for the test. All numbers indicate the sample quantity for each capacitance value tested. If a range is tested, then the quantity indicated in this table will apply to both the highest capacitance and the lowest capacitance and to any other intermediate value required to be tested in the range according to 5.3.1.

NOTE 2 A capacitor which fails on more than one test is counted as one defective capacitor.

NOTE 3 For groups 1, 3 and 4, a retest is allowed with 1 failure. No failures are allowed in these retests.

NOTE 4 For group 2, no retest is required with 0 or 1 failure. With two failures, a retest is required with no failure allowed in this retest.

NOTE 5 For group 5, see 5.16 which allows a retest under special conditions in the event of one failure.

NOTE 6 Three samples of terminal housing (parts of insulating material retaining terminals in position) are needed for the tests described on 5.17

One sample is required for the ball-pressure test (5.17.1) one for the glow-wire test (5.17.2) and one for the tracking test (5.17.3).

When the number of defects for each group and the total number of defective capacitors do not exceed the figures indicated in Table 1, the capacitor model shall be deemed to comply with this standard.

When a capacitor is designed to operate under two or more different conditions (rated voltages, classes, rated duty cycles, etc.), the following tests shall be performed, once only, at the highest test voltage:

a) voltage test between terminals (see 5.7);

b) voltage test between terminals and case (see 5.8);

c) self-healing test (see 5.15).

The endurance test shall be performed for every voltage rating and under every operating condition marked on the capacitor. The number of samples to be inspected shall be calculated accordingly.

5.4 Routine tests

5.4.1 Test procedure

Capacitors shall be subjected to the following tests in the stated order:

a) sealing test, if applicable (see 5.12);
b) voltage test between terminals (see 5.7);
c) voltage test between terminals and case (see 5.8);
d) visual examination (see 5.6);
e) capacitance measurement (see 5.9);
f) tangent of loss angle (see 5.5).

5.5 Tangent of loss angle

The tangent of loss angle limit and measuring frequency shall be defined by the manufacturer.

5.6 Visual examination

The condition, workmanship, marking and finish shall be satisfactory. The marking shall be legible during the life of the capacitor.

5.7 Voltage test between terminals

In type tests, capacitors shall be subjected to an a.c. voltage test as specified in Table 2a or Table 2b. The test shall be carried out with a substantially sinusoidal voltage at the rated frequency. The test may be carried out at 50 Hz or 60 Hz.

A higher frequency may be used at the manufacturer's discretion.

IMPORTANT NOTE

All European countries and countries not specifically named below require tests to be carried out in accordance with Table 2a.

Canada, Japan and USA require that tests are carried out in accordance with Table 2b.

Table 2a – Test voltages

Type of operation	Type of capacitor	Ratio of test voltage to rated voltage a.c.	Type test time s
Continuous	Non-self-healing capacitor	2,15	60
	Self-healing capacitor	2,0	60

For routine tests, the test time in Table 2a may be reduced from 60 s to 2 s.

Table 2b – Test voltages

Type of operation	Type of capacitor	Ratio of test voltage to rated voltage a.c.	Type test time s
Continuous	Non-self-healing capacitor	2,15	10
	Self-healing capacitor	1,75	10

For routine tests, the test time in Table 2b may be reduced from 10 s to 1 s.

No flashover or permanent breakdown shall occur. For metallized capacitors, self-healing may occur.

When the capacitor comprises more than one section, each section shall be tested independently in accordance with the above table.

5.8 Voltage test between terminals and case

Capacitors shall be capable of withstanding without breakdown, for 60 s, a test between terminals (joined together) and the case, with a substantially sinusoidal a.c. voltage of a frequency as near as possible to the rated frequency and of the following r.m.s. value:

twice the rated voltage +1 000 V but not less than 2 000 V.

If the capacitor case is of insulating material, in type tests the test voltage shall be applied between the terminals and the metal mountings, if any, or between the terminals and a metal foil wrapped tightly round the surface of the case. In routine tests the test voltage shall be applied between the terminals and a metal part, if any.

No routine test is required if the case is made entirely of insulating material.

During the test, no dielectric breakdown or flashover shall occur.

For routine tests, the duration may be reduced from 60 s to 2 s for countries using Table 2a or 1 s for countries using Table 2b.

5.9 Capacitance measurement

The capacitance shall be measured using a method which excludes errors due to harmonics.

The precision of measurement shall be better than 5 % of the total tolerance band. For type tests the absolute precision shall be 0,2 % maximum.

Type and routine testing shall be carried out at between 0,9 and 1,1 times the rated voltage and at the rated frequency.

Other measuring voltages and frequencies are permitted if it can be demonstrated that the capacitance measured does not deviate from the true value by more than 0,2 %.

5.10 Check of dimensions

Dimensions of the case, of the terminals and of the fixing arrangements shall comply with those indicated in the drawing, taking tolerances into account.

In addition, minimum creepage distances and clearances indicated in Table 5 shall be checked.

5.11 Mechanical tests

These tests shall be carried out in conformity with the relevant test in IEC 60068 series.

These tests are as follows:

– robustness of terminations: Test U, IEC 60068-2-21;
– soldering: Test T, IEC 60068-2-20;

– vibration (sinusoidal): Test Fc, IEC 60068-2-6.

5.11.1 Robustness of terminations

The capacitor shall be subjected to tests Ua, Ub, Uc and Ud of IEC 60068-2-21, as applicable.

5.11.1.1 Test Ua – Tensile

The load to be applied shall be 20 N for all types of terminations.

For external wire terminations, the cross-sectional area shall be at least 0,5 mm^2.

5.11.1.2 Test Ub – Bending (half of the terminations)

This test shall be carried out only on wire terminations. Two consecutive bends shall be applied.

5.11.1.3 Test Uc – Torsion (other half of the terminations)

This test shall be carried out only on wire terminations. Two successive rotations of 180° shall be applied.

5.11.1.4 Test Ud – Torque (screw terminals)

This test shall be carried out on threaded terminations.

The nuts or screws shall be tightened to the torque specified in Table 3 and loosened again. The torque shall be applied gradually. The screw material shall have adequate resistance against stress cracking.

Table 3 – Torque

Thread diameter mm	Torque N · m
2,6	0,4
3,0	0,5
3,5	0,8
4,0	1,2
5,0	1,8
5,5	2,2
6,0	2,5
8	5
10	7
12	12

5.11.1.5 Visual examination

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

5.11.2 Soldering

This test shall be carried out only when terminals are designed for connection by soldering.

The capacitor shall then be subjected to test T of IEC 60068-2-20 either using the solder bath method or the solder globule method.

When neither the solder bath method nor the solder globule method is applicable, the soldering iron test shall be used, with soldering iron size A.

Before and after the test the capacitance of the capacitor shall be measured by the method laid down in 5.9. No perceivable capacitance change is permitted.

When the test procedures have been carried out, the capacitors shall be visually examined. There shall be no visible damage.

5.11.3 Vibration

The capacitors shall be subjected to test Fc of IEC 60068-2-6 using a mounting system similar to that which is to be used in practice. The severity of the test shall be as follows:

– f = 10 Hz to 55 Hz;
– a = ±0,35 mm;
– test duration per axis = 10 frequency cycles (3 axes offset from each other by 90°), 1 octave per minute.

Before and after the test, the capacitance of the capacitors shall be measured by the method laid down in 5.9. No perceivable capacitance change is permitted.

After the test, the capacitor shall be subjected to the voltage test between terminals and case according to 5.8. No dielectric breakdown or flashover shall occur.

When all the test procedures have been carried out, the capacitors shall be visually examined. There shall be no visible damage.

5.11.4 Fixing bolt or stud (if fitted)

Fixing threaded bolts and attachments to the capacitor body shall have adequate resistance to ageing deterioration in service.

The durability of the fixing bolt or stud shall be checked on four of the samples tested in 5.13 (endurance test) by the following method.

Four of the capacitors shall be mounted on a fixing plate in the endurance test chamber. The thickness of the fixing plate shall be 1,5 mm ± 0,1 mm and the diameter of the hole shall be the base bolt diameter +0,5 mm to +1,0 mm.

Prior to commencement of the endurance test, torque values specified in Table 3 are to be applied. On completion of the endurance test, a torque figure of one-half the appropriate value specified in Table 3 shall be applied.

No failures are permitted.

5.12 Sealing test

This test is not required if the manufacturer certifies that capacitors do not contain substances that are liquid at t_c + 10 °C.

The capacitor shall be mounted in a position most likely to reveal leakage at a temperature 10 °C ± 2 °C higher than the maximum permissible capacitor operating temperature for a time sufficient for all parts of the capacitor to reach this temperature.

The capacitor shall be maintained at this temperature for a further hour before cooling.

No leakage shall occur.

If the capacitor is intended to be supplied with a terminal cover, the sealing test should preferably be carried out before fastening the cover. The cover shall be fastened in such a manner that the sealing is not impaired.

After the sealing test, capacitors shall be inspected for liquid leakage and distorted case.

Liquids are allowed to wet the surface but not to form droplets.

5.13 Endurance test

This test is intended to prove the suitability of the capacitor design for the class of operation specified by the manufacturer.

For capacitors fitted with base bolts, refer also to 5.11.

The method indicated below is intended to ensure that the capacitor case temperature is as close as possible to the maximum permissible capacitor operating temperature.

5.13.1 Testing in air with forced circulation

The capacitors shall be mounted in a test chamber in which the temperature of the air is constant within a tolerance of ±2 °C.

The air in the test chamber shall be continuously agitated but not so vigorously as to cause undue cooling of the capacitors. The capacitors under test shall not be subjected to direct radiation from any heating elements in the chamber.

The sensitive element of the thermostat regulating the air temperature of the chamber shall be well within the stream of heated circulating air.

NOTE Heating of the air may take place in a separate chamber, from which the air can be admitted to the capacitor test chamber through a valve allowing good distribution of heated air over the capacitors.

The capacitors are mounted in a position most favourable to the leakage of impregnant or filling material.

The distance between cylindrical capacitors shall not be less than their diameter, and the distance between rectangular capacitors shall not be less than twice the shorter side of their base.

The temperature sensitive element of a temperature recording instrument shall be attached half-way up the side of the case of the capacitor with the lowest value of tangent of loss angle.

The thermostat shall be set to (t_C – 15 °C), and capacitors are then energized according to the appropriate voltage and test cycle (see also Annex A). During the first 24 h, the difference between t_C and the indication of the temperature recording instrument shall be noted, and adjustments made to ensure the temperature of each capacitor case is at t_C ± 2 °C. The test is then continued to the end of the appropriate time without further adjustment of the thermostat, the time being measured from the first energization of the capacitors.

NOTE It is recommended that each test capacitor is individually protected by a circuit-breaker or fuse.

5.13.2 Endurance test procedure

Capacitors shall be tested according to the appropriate class indicated in Table 4.

Table 4 – Endurance test conditions

Life expectancy	30 000 h (class A)	10 000 h (class B)	3 000 h (class C)	1 000 h (class D)
Test conditions	6 000 h at 1,25 U_N continuous or 3 000 h at 1,35 U_N continuous	2 000 h at 1,25 U_N continuous or 1 000 h at 1,35 U_N continuous	600 h at 1,25 U_N continuous	200 h at 1,25 U_N continuous
Permitted capacitance change	3 %	3 %	3 %	3 %

Life expectancy classes over 30 000 h are permitted by using the following calculation:

test duration = 10 % of life at 1,35 U_N and 20 % of life at 1,25 U_N.

The test times given in Table 4 refer to periods of actual energization.

NOTE The relationship between life expectancy and the endurance test duration is based on experience and on statistics, it does not have an absolute value.

5.13.3 Conditions of compliance

During the test, no permanent breakdown, interruption or flashover shall occur.

No leak should be apparent which forms droplets within 10 min when kept at the upper temperature limit in the most unfavourable position.

At the end of the test, the capacitors shall cool down freely to the ambient temperature and the capacitance shall then be measured (see 5.9).

Intermediate test measurements are permitted.

5.14 Damp-heat test

Capacitance shall be measured before the test (see 5.9).

This test shall be carried out in accordance with IEC 60068-2-78.

The severity indicated in the marking shall be employed. No voltage shall be applied to the samples and no measurement shall be taken during the test.

After the damp-heat period, the capacitors shall be stored under standard atmospheric conditions for recovery for not less than 1 h and not more than 2 h. Immediately after recovery, the capacitance shall be measured in accordance with 5.9.

Capacitance change shall be less than 0,5 % after the test.

5.15 Self-healing test

Self-healing capacitors shall have adequate self-healing properties. Compliance is checked by the following test.

This test shall be applied only to capacitors marked  or SH.

The capacitors shall be subjected to the test described in 5.7 for the test time indicated in the appropriate table.

If fewer than five self-healing breakdowns (clearings) occur during this time, the voltage shall be increased at a rate of not more than 200 V/min until five clearings have occurred since the beginning of the test or until the voltage has reached a maximum of 3,5 U_N.

The voltage shall then be decreased to 0,8 times the voltage at which the fifth clearing occurred or 0,8 times the maximum voltage and maintained for 10 s. One additional clearing in each capacitor shall be permitted during this period.

The capacitors shall be deemed to have passed the test if they meet both of the following requirements:

a) change of capacitance is $< 0,5$ %;

b) RC value is ≥ 100 s.

Self-healing breakdowns during the test may be detected by an oscilloscope or by acoustic or high-frequency test methods.

5.16 Destruction test

5.16.1 General

This test is optional.

Refer to revised definition 3.22 for the appropriate test for each class of safety protection.

Capacitors marked S0 are not required to be tested in accordance with this subclause.

Capacitors fitted with overpressure disconnect device designated S1 and S2 shall be subjected to the sequential DC and AC test described in 5.16.3 and 5.16.5.

Capacitors with segmented film as defined in 3.6 and designated S3 class of safety protection shall be subjected to the simultaneous DC and AC test described in 5.16.4 and 5.16.6.

For capacitors designated S1, S2 and S3 refer to Figure 1.

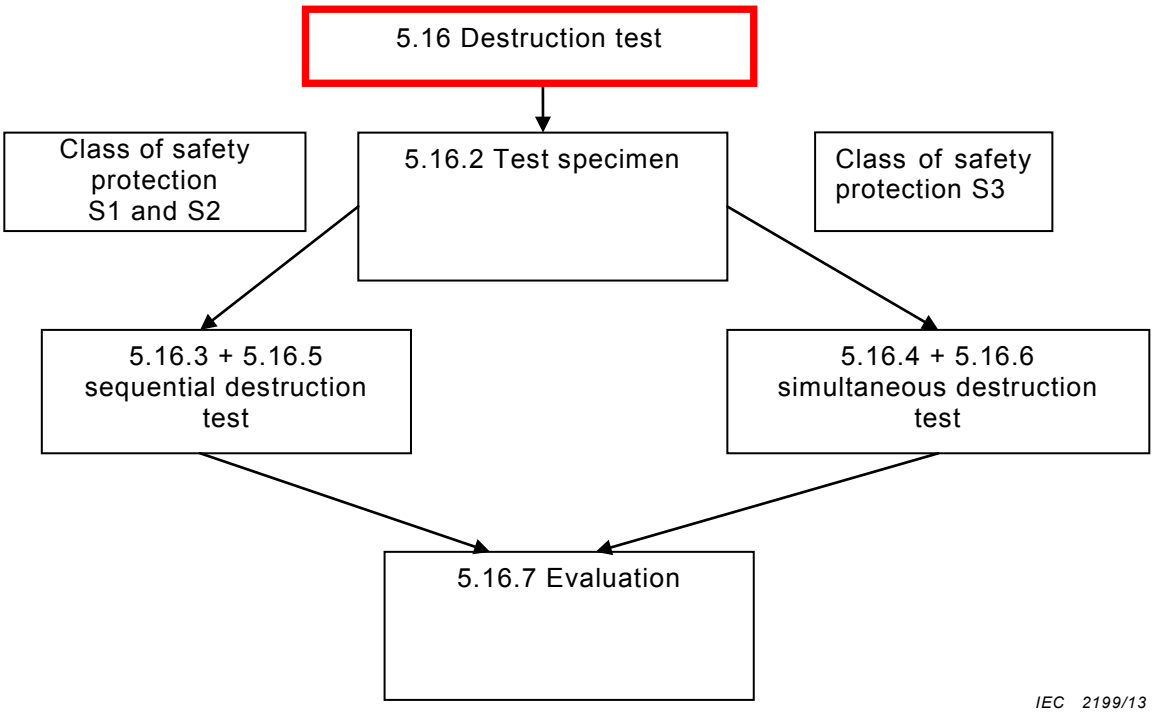


Figure 1 – Destruction test

5.16.2 Test specimens

The test is to be carried out on 10 samples, with a similar specimen of 10 samples held in reserve for possible retest. Half the test specimens (5) shall have passed the test according to 5.4.1. The remaining five capacitors shall have passed the endurance test described in 5.13 (group 2).

For capacitors with a metal case, the metal case shall be connected to one of the terminals of the voltage source.

If a distinction can be made between the capacitor terminals, the group shall be subdivided into two subgroups. The first subgroup shall have terminal A connected to the case, the second subgroup shall have terminal B connected to the case.

5.16.3 Test apparatus for sequential DC and AC test (capacitor type S1 and S2)

5.16.3.1 Test apparatus for d.c. conditioning

Apparatus for carrying out the d.c. conditioning is shown in Figure 2. The d.c. source shall be capable of delivering an open-circuit voltage equivalent to 10 U_N and have a sustained shortcircuit capability greater than 50 mA.

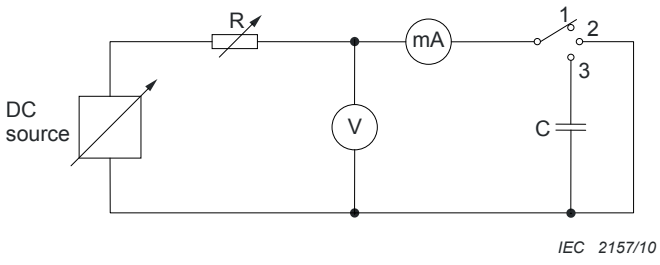


Figure 2 – Test apparatus for d.c. conditioning

The d.c. source is adjusted to provide an open-circuit voltage equivalent to 10 U_N with the switch in position 1.

A variable resistor R is adjusted to provide a current of 50 mA with the switch in position 2.

DC voltage is applied to the test capacitor with the switch in position 3.

5.16.3.2 Test apparatus for a.c. destruction test

a) The instantaneous short-circuit current of the a.c. supply shall be at least 300 A.
b) A 25 A slow-blow fuse and adjustable inductance (L) shall be inserted between the a.c. source and the capacitor (see Figure 3).

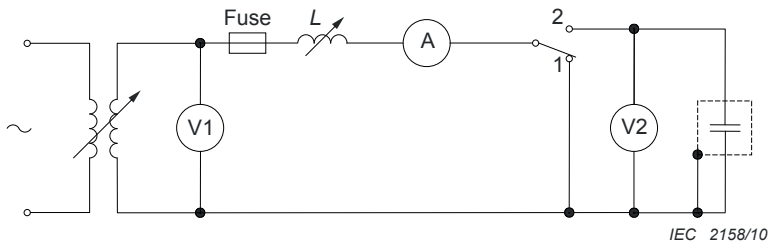


Figure 3 – Test apparatus for a.c. destruction test

The inductor shall be so adjusted that, with the switch in position 1 and a voltage of 1,3 U_N applied across the voltmeter V1, a current equal to 1,3 times the capacitor rated current (I_N) flows.

The capacitor is energized with the switch in position 2.

NOTE The variable inductor L in Figure 3 may be replaced by the arrangement shown in Figure 4 whereby T2 is a fixed ratio transformer and L_f is a fixed inductor. A variable ratio transformer T1 is used to adjust the inductive current.

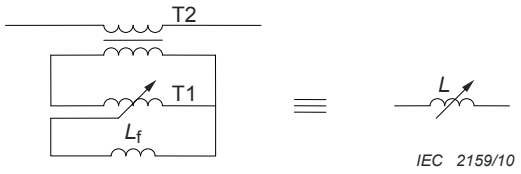
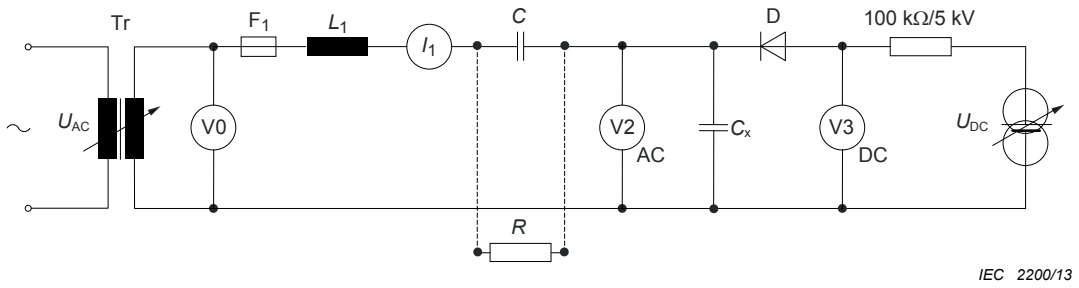


Figure 4 – Arrangement to produce the variable inductor *L* in Figure 3

5.16.4 Test apparatus for simultaneous DC and AC test (capacitor type S3)

Apparatus for carrying out the simultaneous DC and AC test is shown in Figure 5. The d.c. source (U_{dc}) shall be capable of delivering an open-circuit voltage equivalent to 10 U_N and shall have a sustained short-circuit capability greater than 50 mA but limited to 50 mA during the test.



Tr Transformer (AC power supply) with sufficient capacity to supply an instantaneous short-circuit current of at least 300 A

F_1 Slow-blow fuse, rated 25 A

L_1 Inductor of approximately 10 mH for grid decoupling (resonant free in all switching modes)

C Capacitor for DC decoupling: $C \geq 10 \times C_x$ (e.g. C = 330 μF -->C_{xmax} = 33 μF)/U_{cmax} = 5 kV

C_x Capacitor under test

D High voltage diode for AC decoupling

I_1 AC current: 1,3 × I_R at the beginning of the test when the capacitor is full operative (I_R = Rated current of the capacitor under test)

V2 AC test voltage: 1,3 × U_R (U_R = Rated voltage of the capacitor under test)

V3 DC test voltage: Voltage increase from 0 V to max. 10 × U_R at a rate of 200 V/min (U_R = Rated voltage of the capacitor under test)

R Resistor for capacitor discharging at the end of the test

Figure 5 – Test apparatus for simultaneous DC and AC

5.16.5 Test procedure for sequential DC and AC test (capacitor type S1 and S2)

5.16.5.1 General

The test shall be conducted in four stages:

- 5.16.5.2 Preparation and pre-conditioning,
- 5.16.5.3 DC conditioning,
- 5.16.5.4 AC destruction test,
- 5.16.7 Evaluation of the failure.

NOTE The purpose of the d.c. conditioning is to produce a dielectric breakdown condition. It is not the intention that d.c. conditioning is used to create open-circuit capacitors.

5.16.5.2 Preparation and pre-conditioning

All the test specimens shall be prepared and pre-conditioned as follows:

The capacitors shall be wrapped closely in tissue paper complying with 6.86 of ISO 4046:2002 and mounted within an "air circulating" test chamber at t_c + 10 °C. The temperature deviation shall not exceed ±2 °C. In preparation for the destruction test, the specimens shall have rated voltage (U_N) applied for 2 h at t_c + 10 °C.

No open-circuit or short-circuit capacitors are permitted. If this occurs, the type shall be declared a failure.

5.16.5.3 DC conditioning

Five capacitors that have passed the endurance test (group 2) shall be pre-heated to a temperature of t_c + 10 °C before d.c. conditioning. The remaining five capacitors, having passed the test in 5.4.1 shall be tested at room temperature.

The voltage of a d.c. source (see Figure 2) shall be raised from zero to a maximum of 10 U_N at a rate of approximately 200 V/min until a short-circuit occurs or 10 U_N has been reached.

Capacitors shall be removed from d.c. conditioning when the voltage indicated on the voltmeter is zero or 10 U_N has been reached and maintained for a period of 5 min or other period as defined by the manufacturer.

A capacitor that becomes open-circuit after the d.c. conditioning shall be replaced by another sample and not counted. The d.c. conditioning test may be repeated on new samples until all the 10 reserve specimens referred to in 5.16.1 have been used up. If the required number of capacitors with dielectric breakdown cannot be achieved, then the test shall be regarded as failed.

5.16.5.4 AC destruction test

With the capacitors maintained at the d.c. conditioning temperature, they shall then have applied an a.c. voltage of 1,3 U_N (see Figure 3). If the capacitor clears (becomes operative) or becomes open-circuit, the voltage shall be maintained for 5 min. If the capacitor is still operative after 5 min then the d.c. conditioning shall be repeated.

If the capacitor becomes short-circuit, then the test shall be maintained for 8 h.

5.16.6 Test procedure for simultaneous DC and AC test (capacitor type S3)

5.16.6.1 Preparation and pre-conditioning

Same as 5.16.5.2.

5.16.6.2 Simultaneous DC and AC test

Five capacitors that have passed the endurance test (group 2) shall be pre-heated to a temperature of $t_c + 10$ °C before testing. The remaining five capacitors, having passed the test in 5.4.1 shall be tested at room temperature.

Apply a constant a.c. voltage of 1,3 U_N at U_{ac1} (V_2) and measure the initial current (I_1).

The voltage of a d.c. source U_{dc1} (V_3) shall be raised from zero to a maximum of 10 U_N at a rate of approximately 200 V/min until the capacitor becomes inoperative or 10 U_N has been reached.

The capacitor shall be considered as failed if it does not become inoperative (capacitance <1 % C_N) within 5 minutes at 10 U_N.

The d.c. current shall be limited to 50 mA.

NOTE Inoperative means the current is lower than 1 % of the initial current measured at the same a.c. voltage and frequency as the initial measurement.

5.16.7 Evaluation of the failure

After completion of the test, the tissue paper shall not have burnt on any test specimen; however, it may be discoloured by escaping substances.

Each capacitor shall meet the following:

a) escaping liquid material may wet the outer surface of the capacitor, but not fall away in drops;

b) internal live parts shall not be accessible to the standard test finger (see Figure 1 of IEC 60529:2001);

c) burning or scorching of the tissue paper shall not be evident, since this would indicate that flames or fiery particles have been emitted from the openings;

d) the capacitor shall withstand the test of 5.8 with the voltage being reduced to 0,8 times the value indicated.

The test is concluded when 10 capacitors have become short circuit or open circuit (for capacitors type S1), open circuit (for capacitors type S2) or inoperative with capacitance measuring <1 % C_N (for capacitors type S3).

If one of the test specimens does not satisfy the criteria according to a) or d) above, the test may be repeated once on a further 10 samples. However, all capacitors shall pass the repeat test.

If more than one capacitor does not satisfy the criteria according to a) or d), then the test shall be regarded as failed. All capacitors must satisfy the requirements of b) and c).

5.17 Resistance to heat, fire and tracking

These tests are not applicable to capacitors with lead terminations.

5.17.1 Ball-pressure test

External parts of insulating material retaining terminals in position shall be sufficiently resistant to heat.

For materials other than ceramic, compliance is checked by subjecting the parts to the ball-pressure test in accordance with 27.3 of IEC 60309-1 at 125 °C or at t_c + 40 °C, whichever is the higher.

5.17.2 Glow-wire test

For materials other than ceramic, compliance is also checked by the following test.

External parts of insulating material retaining terminals in position shall be subjected to the glow-wire test in accordance with IEC 60695-2-10 and IEC 60695-2-11, subject to the following details:

- the test sample comprises one set of individual components forming the terminal assembly;
- the temperature of the tip of the glow-wire is 550 °C for $I_N \leq 0{,}5$ A and 850 °C for $I_N > 0{,}5$ A;
- any flame or glowing of the specimen shall extinguish within 30 s of withdrawing the glow-wire, and any flaming drops shall not ignite a piece of five-layer wrapping tissue, as defined in ISO 4046, spread out horizontally at a distance of 200 mm $\pm$ 5 mm below the place where the glow-wire is applied to the specimen.

5.17.3 Tracking test

Outer insulating parts of capacitors which retain live parts in position or are in contact with such terminals shall be of material resistant to tracking.

Compliance is checked by carrying out the tracking test specified in IEC 60112 at 250 V on relevant parts according to solution A.

6 Permissible overloads

6.1 Maximum permissible voltage

Irrespective of their type of operation, metal-foil and metallized capacitors shall be suitable for operation under abnormal conditions for prolonged periods at an r.m.s. voltage between terminals not exceeding 1,10 times the rated voltage, excluding transients caused by switching the capacitors in and out of circuit (see 9.2, 9.3 and 9.5) but including the effects of harmonics and supply voltage variations.

Operation above the rated voltage will reduce the life expectancy of the capacitor.

6.2 Maximum permissible current

Capacitors shall be suitable for operation at an r.m.s. current not exceeding 1,30 times the current which occurs at rated sinusoidal voltage and rated frequency excluding transients.

Taking into account the capacitance tolerance, the maximum permissible current can be up to 1,30 times the rated current increased in proportion to the actual capacitance value compared with the rated capacitance value.

6.3 Maximum permissible reactive output

The overload resulting from operation at voltage and current exceeding the rated values (though within the limits indicated in 6.1 and 6.2) shall not exceed 1,35 times the rated output.

Taking into account the capacitance tolerance the maximum permissible output can be up to 1,35 times the rated output increased in proportion to the actual capacitance value compared with the rated capacitance value.

NOTE It should be noted that operation of capacitors with overload, even within the limit indicated above, may adversely affect the life duration of these capacitors.

7 Safety requirements

7.1 Creepage distances and clearances

The creepage distances over external surfaces of terminal insulation and the clearances between the exterior parts of terminal connections or between such live parts and the metal case of the capacitor, if any, shall be not less than the minimum values given in Table 5.

These minimum distances shall apply to the terminals with or without the external wiring connected. They are not intended to apply to internal creepage distances and clearances.

The requirements for specific applications shall be satisfied.

The contribution to the creepage distances of any groove less than 1 mm wide shall be limited to its width.

Any air-gap of less than 1 mm shall be ignored in calculating the total air path.

Creepage distances are distances in air, measured along the surface of insulating material.

7.2 Terminals and connecting cables

Terminals and undetachable connecting cables shall have a conductor cross-section which can safely carry the current of the capacitor and shall have sufficient mechanical strength.

The minimum cross-sectional area of the conductor shall be 0,5 mm^2. Insulated cables shall conform to the voltage and temperature ratings of the capacitor.

Manufacturers shall provide evidence that the cable supplied with the capacitor shall adequately carry the current over the full capacitance/temperature/voltage range specified.

7.3 Earth connections

If the metal case of the capacitor is intended to be connected to earth or to a neutral conductor, means shall be provided to enable an effective connection to be made. This may be achieved by supplying the capacitor in an unpainted metal case or by provision of an earth terminal, an earth conductor, or a metal bracket with sound electrical connection to the case.

Whichever the type of connection used, it must be clearly marked by the symbol ⏚ as the earth connection.

When the metal case is provided with a threaded stud and the capacitor is securely fixed to the metal frame by means of this stud without interposed insulating material and the frame is securely connected to earth, the stud shall be considered as an effective connection to earth.

Table 5 – Minimum creepage distances and clearances

Rated voltage	**Up to and including 24 V** mm	**Above 24 V up to and including 250 V** mm	**Above 250 V up to and including 500 V** mm	**Above 500 V up to and including 1 000 V** mm
Creepage distances				
1 Between live parts of different polarity	2	3 (2)	5	6
2 Between live parts and accessible metal parts which are permanently fixed to the capacitor including screws or devices for fixing covers or fixing the capacitor to its support	2	4 (2) 3[a]	6 3[a]	7
Clearances				
3 Between live parts of different polarity	2	3 (2)	5	6
4 Between live parts and accessible metal parts which are permanently fixed to the capacitor including screws or devices for fixing covers or fixing the capacitor to its support	2	4 (2) 3[a]	6 3[a]	7
5 Between live parts and a flat supporting surface or a loose metal cover, if any, if the construction does not ensure that the values under item 4 above are maintained under the most unfavourable conditions (for information only)	2	6	10	12
NOTE The values in brackets apply to creepage distances and clearances protected against dirt. For permanently sealed-off or compound-filled cases, creepage distances and clearances are not checked.				
Item 5 has been included for guidance only to indicate requirements for the capacitor in the application.				
[a] For glass or other insulation with equivalent tracking qualities.				

7.4 Discharge devices

In many cases, discharge devices are not required; namely, when the capacitor is connected permanently to the motor winding, or when placed in an inaccessible position.

When a discharge device is specified, it must reduce the voltage at the terminals from the peak of the rated voltage to a value of 50 V or less in the time of 1 min from the moment the capacitor is switched off.

NOTE A discharge device may sometimes be specified, not for safety reasons, but to prevent electrical overstress on the capacitor. This may occur when a disconnected capacitor still charged is reconnected across another capacitor of different polarity.

8 Marking

The following information shall be marked on the capacitor:

a) manufacturer's name, abbreviated name or trade mark;

b) manufacturer's type designation;

c) rated capacitance (C_N) in microfarads and tolerance as a percentage;

d) rated voltage (U_N) in volts;

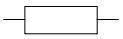
e) spare;

f) rated frequency f_N, in hertz, if other than 50 Hz;

g) climatic category, for example 25/85/21 (see 4.1);

h) date of manufacture (a code may be used);

i)  or SH for self-healing capacitors;

j) discharge device, if any, shall be written out in full or indicated by the symbol 

k) class of safety protection, for example, S0, S1, S2, S3;

l) approval marks;

m) filling material. Reference to liquid used (not needed for dry capacitors);

n) class of operation or life duration. To be positioned adjacent to the voltage;

o) specification (standard) number.

If the capacitor is small and has not enough space for marking, items a), b), c), d), g), h), i), k), l), n) shall be marked and other items can be omitted. Furthermore, item c) may be marked by the standard code according to IEC 60062 but, if there is enough space available the rated capacitance and the capacitance tolerance shall be marked in clear text.

Information omitted on the capacitor shall be indicated on the packaging or on the accompanying notice.

9 Guidance for installation and operation

9.1 General

Unlike most electrical apparatus, motor capacitors are not connected to power systems as independent apparatus. In each case, the capacitor is connected in series with an inductive winding on the motor and may also be in physical contact with the motor or other apparatus. The characteristics of the motor and such other apparatus exert a strong influence on the operating conditions of the capacitors.

The most important influences on motor capacitors are the following:

– where a motor capacitor is connected in series with the auxiliary winding of a single-phase induction motor, the voltage at the terminals of the capacitor at operating speed is generally considerably higher than the mains voltage;
– when in physical contact with the motor, the capacitor is not only stressed by vibration of the motor but also by the heat transferred from the energized windings and the active iron. Also, other sources of heat such as the heating of an electric washing machine may raise the temperature of the capacitor.

Most capacitor motors, and consequently the capacitors also, are switched on and off frequently. In switching tests, it has been found that high transients often occur at the terminals of both the running and starting capacitors. To withstand these transients, care should be exercised to ensure that the manufacturer's declared ratings are not exceeded.

9.2 Choice of rated voltage

9.2.1 Measurements of working voltage

With maximum mains voltage, motor inductance and capacitance (taking into account tolerances and motor loads for worst conditions), the voltage across the capacitor shall not exceed 10 % above the capacitor rated voltage.

9.2.2 Influence of capacitance

Apart from the supply system voltage and the inductive coupling between the main winding and the auxiliary winding of the capacitor motor, the voltage at the terminals of the capacitor depends on the value of the capacitance itself, especially when the capacitor and the auxiliary winding operate near the resonance point. This fact should be taken into account when choosing the rated voltage of the capacitor and due attention should also be paid to the maximum permissible motor current.

In choosing the rated voltage of the capacitor, due attention should be paid to the voltage measurements specified in 9.2.1, to the possible variation in the mains voltage and to the effect of the capacitance tolerance.

9.3 Checking capacitor temperature

9.3.1 Choice of maximum permissible capacitor operating temperature

Since many factors influence the temperature conditions of motor capacitors, which cannot easily be calculated beforehand (heat radiation and heat conduction from the motor, high ambient temperature, bad cooling conditions, etc.), the user should check the capacitor operating temperature in association with the apparatus into which the capacitor is built. During this test, the most unfavourable permissible conditions of operation applicable to the apparatus should be attained.

Under these conditions, the capacitor temperature should be measured. The rated maximum permissible capacitor operating temperature should be not less than the highest temperature measured during this test.

Before changing the capacitor type, this test shall be repeated.

9.3.2 Choice of minimum permissible capacitor operating temperature

The rated minimum permissible capacitor operating temperature shall not be higher than the lowest ambient temperature at which the capacitor may be operated.

9.4 Checking transients

Under certain conditions of switching motors on or off, or the switching of starting capacitors across run capacitors, high current surges or transient overvoltages may occur. To prevent

premature capacitor failure, the user shall establish by appropriate tests, that the manufacturer's declared value of maximum transient voltage and maximum d*v*/d*t* are not exceeded. Under some circumstances, discharge resistors or series resistance may need to be considered in the motor circuit to limit voltage and current surges.

In some circumstances it may be necessary to add resistance to reduce the peak current to within the capacitor's design ratings.

9.5 Leakage current

Capacitive leakage current is not normally significant for motor applications. However, where the application requires low leakage to earth, this should be specifically requested by the user.

Annex A
(normative)

Test voltage

Voltage tests are carried out with an a.c. source as specified in the relevant clause. The source shall be adequate to maintain, over any specified test period, the test voltage required, subject to a tolerance of ±2,5 %, but ±2 % for the endurance test.

AC voltage tests are made using a 50 Hz or 60 Hz frequency, as appropriate, the voltage waveform of which is sufficiently free from harmonics as to ensure that, when applied to the capacitor, the resulting current does not exceed the value corresponding to a sinusoidal voltage waveform by more than 10 %.

Bibliography

Additional useful information may be found in the following standards:

IEC 60110-1:1998, *Power capacitors for induction heating installations – Part 1: General*

IEC 60143-1: 2004: *Series capacitors for power systems – Part 1: General*

IEC 60252-2[1], AC motor capacitors – Motor start capacitors

IEC 60358:1990, *Coupling capacitors and capacitor dividers*

IEC 60831-1:2002, *Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V – Part 1: General – Performance, testing and rating – Safety requirements – Guide for installation and operation*

IEC 60871-1:2005, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 1: General*

IEC 60931-1:1996, *Shunt power capacitors of the non-self-healing type for a.c. systems having a rated voltage up to and including 1 000 V – Part 1: General – Performance, testing and rating – Safety requirements – Guide for installation and operation*

IEC 61048: 2006, *Auxiliaries for lamps – Capacitors for use in tubular fluorescent and other discharge lamp circuits – General and safety requirements*

IEC 61071:2007, *Power electronic capacitors*

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1 To be published.

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