

Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V —

Part 1: General

The European Standard EN 60871-1:2005 has the status of a
British Standard

ICS 29.240.99; 31.060.70

National foreword

This British Standard is the official English language version of EN 60871-1:2005. It is identical with IEC 60871-1:2005. It supersedes BS EN 60871-1:1998 which will be withdrawn on 1 October 2008.

The UK participation in its preparation was entrusted to Technical Committee PEL/33, Power capacitors, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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English version

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

Condensateurs shunt pour réseaux à
courant alternatif de tension assignée
supérieure à 1 000 V
Partie 1: Généralités
(CEI 60871-1:2005)

Parallelkondensatoren für
Wechselspannungs-Starkstromanlagen
mit einer Nennspannung über 1 kV
Teil 1: Allgemeines
(IEC 60871-1:2005)

This European Standard was approved by CENELEC on 2005-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

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

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CENELEC

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

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Foreword

The text of document 33/411/FDIS, future edition 3 of IEC 60871-1, prepared by IEC TC 33, Power capacitors, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60871-1 on 2005-10-01.

This European Standard supersedes EN 60871-1:1997.

The main changes with respect to EN 60871-1:1997 regard the modification of the values of the test voltage during the voltage test between terminals and the introduction of the clause concerning the choice of creepage distances and air clearances.

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2006-07-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2008-10-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60871-1:2005 was approved by CENELEC as a European Standard without any modification.

CONTENTS

1	Scope and object.....	6
2	Normative references	7
3	Terms and definitions	7
4	Service conditions	10
4.1	Normal service conditions.....	10
4.2	Unusual service conditions	11
5	Quality requirements and tests	11
5.1	General.....	11
5.2	Test conditions	11
6	Classification of tests	11
6.1	Routine tests	11
6.2	Type tests	12
6.3	Acceptance tests	12
6.4	Endurance test (special test)	12
7	Capacitance measurement (routine test).....	13
7.1	Measuring procedure.....	13
7.2	Capacitance tolerances	13
8	Measurement of the tangent of the loss angle ($\tan \delta$) of the capacitor (routine test)	14
8.1	Measuring procedure.....	14
8.2	Loss requirements	14
8.3	Losses in external fuses	14
9	Voltage test between terminals (routine test)	14
9.1	AC test.....	14
9.2	DC test.....	14
10	AC voltage test between terminals and container (routine test)	15
11	Test of internal discharge device (routine test).....	15
12	Sealing test (routine test)	15
13	Thermal stability test (type test).....	16
13.1	General.....	16
13.2	Measuring procedure.....	16
14	Measurement of the tangent of the loss angle ($\tan \delta$) of the capacitor at elevated temperature (type test)	17
14.1	Measuring procedure.....	17
14.2	Requirements	17
15	AC voltage test between terminals and container (type test).....	17
16	Lightning impulse test between terminals and container (type test).....	18
17	Short-circuit discharge test (type test).....	18
18	Insulation levels	19
18.1	Standard insulation values.....	19
18.2	General requirements	19
18.3	Test between terminals and container of capacitor units.....	20
18.4	Capacitors in single-phase systems	20
19	Overloads – Maximum permissible voltage	

19.1	Long duration voltages	23
19.2	Switching overvoltages	24
20	Overloads – Maximum permissible current	24
21	Safety requirements for discharge devices	24
22	Safety requirements for container connections	25
23	Safety requirements for protection of the environment	25
24	Other safety requirements	25
25	Markings of the capacitor unit	25
25.1	Rating plate	25
25.2	Standardized connection symbols	26
25.3	Warning plate	26
26	Markings of the capacitor bank	26
26.1	Instruction sheet or rating plate	26
26.2	Warning plate	26
27	Guide for installation and operation	27
27.1	General	27
27.2	Choice of the rated voltage	27
27.3	Operating temperature	28
27.4	Special service conditions	29
27.5	Overvoltages	29
27.6	Overload currents	31
27.7	Switching and protective devices	32
27.8	Choice of insulation levels	33
27.9	Choice of creepage distances and air clearance	36
27.10	Capacitors connected to systems with audio-frequency remote control	38
Annex A (normative)	Precautions to be taken to avoid pollution of the environment by polychlorinated biphenyls	39
Annex B (normative)	Additional definitions, requirements and tests for power filter capacitors	40
Annex C (normative)	Test requirements and application guide for external fuses and units to be externally fused	42
C.1	General	42
C.2	Definitions	42
C.3	Performance requirements	42
C.4	Tests	42
C.5	Guide for co-ordination of fuse protection	43
C.6	Choice of fuses	43
C.7	Information needed by the user of the fuses	44
Annex D (informative)	Formulae for capacitors and installations	45
D.1	Computation of the output of three-phase capacitors from three single-phase capacitance measurements	45
D.2	Resonant frequency	45
D.3	Voltage increase	45
D.4	Inrush transient current	45
D.5	Discharge resistance in single-phase unit	46
D.6	Discharge time to 10 % of rated voltage	46
Annex E (informative)	Capacitor bank fusing and unit arrangement	47
E.1	Internally fused capacitor bank	47

E.2 Externally fused capacitor bank	47
E.3 Fuseless capacitor bank	48
Annex ZA (normative) Normative references to international publications with their corresponding European publications.....	51
Bibliography	50
Figure 1 – Bank isolated from ground.....	35
Figure 2 – Bank isolated from ground (containers connected to ground)	35
Figure 3 – Bank connected to ground.....	36
Figure 4 – Air clearance versus AC withstand	38
Figure E.1 – Typical connections between capacitor units	48
Figure E.2 – Typical connections between elements within a capacitor unit	49
Table 1 – Letter symbols for upper limit of temperature range.....	10
Table 2 – Ambient air temperature for the thermal stability test	16
Table 3 – Standard insulation levels for $U_m < 52$ kV – Series I (based on current practice in most European and several other countries)	20
Table 4 – Standard insulation levels for $U_m < 52$ kV – Series II (based on current practice in some North American and other countries).....	21
Table 5 – Standard insulation levels for $52 \text{ kV} \leq U_m < 300 \text{ kV}$	21
Table 7 – Admissible voltage levels in service.....	23
Table 8 – Insulation requirements	34
Table 9 – Correlation between standard lightning impulse withstand voltages and minimum air clearances (IEC 60071-2, Annex A, Table A.1)	37

SHUNT CAPACITORS FOR AC POWER SYSTEMS HAVING A RATED VOLTAGE ABOVE 1 000 V –

Part 1: General

1 Scope and object

This part of IEC 60871 is applicable to both capacitor units and capacitor banks intended to be used, particularly, for power-factor correction of a.c. power systems having a rated voltage above 1 000 V and frequencies of 15 Hz to 60 Hz.

This part of IEC 60871 also applies to capacitors intended for use in power filter circuits. Additional definitions, requirements and tests for filter capacitors are given in Annex B.

Additional requirements for capacitors protected by internal fuses as well as requirements for the internal fuses are given in IEC 60871-4.

Requirements for capacitors to be protected by external fuses, as well as requirements for the same, are given in Annex C.

This standard does not apply to capacitors of the self-healing metallized dielectric type.

The following capacitors are excluded from this part of IEC 60871:

- capacitors for inductive heat-generating plants operating at frequencies between 40 Hz and 24 000 Hz (IEC 60110-1);
- series capacitors for power systems (see the IEC 60143 series);
- capacitors for motor applications and the like (see the IEC 60252 series);
- coupling capacitors and capacitor dividers (IEC 60358);
- shunt capacitors for a.c. power systems having rated voltage up to and including 1 000 V (see the IEC 60831 and IEC 60931 series);
- small a.c. capacitors to be used for fluorescent and discharge lamps (IEC 61048 and IEC 61049);
- capacitors to be used in power electronic circuits (IEC 61071);
- capacitors for microwave ovens (IEC 61270-1);
- capacitors for suppression of radio interference;
- capacitors intended for use with d.c. voltage superimposed on a.c. voltage.

Accessories such as insulators, switches, instrument transformers, external fuses, etc. are in accordance with the relevant IEC standards.

The object of this part of IEC 60871 is as follows:

- a) to formulate uniform rules regarding the performance and rating of units and banks, and the testing of units ;
- b) to formulate specific safety rules;
- c) to provide a guide 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 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60099 (all parts), *Surge arresters*

IEC 60549:1976, *High-voltage fuses for the external protection of shunt power capacitors*

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

IEC 60871-2:1999, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 2: Endurance testing*

IEC 60871-4:1996, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 4: Internal fuses*

3 Terms and definitions

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

3.1

capacitor element

element

device consisting essentially of two electrodes separated by a dielectric

[IEV 436-01-03]

3.2

capacitor unit

unit

assembly of one or more capacitor elements in the same container with terminals brought out

[IEV 436-01-04]

3.3

capacitor bank

bank

number of capacitor units connected so as to act together

[IEV 436-01-06]

3.4

capacitor

in this part of IEC 60871, the word "capacitor" is used when it is not necessary to lay particular stress upon the different meanings of the words capacitor unit or capacitor bank

3.5**capacitor installation**

one or more capacitor banks and their accessories

[IEV 436-01-07]

3.6**discharge device of a capacitor**

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

[IEV 436-03-15, modified]

3.7**internal fuse of a capacitor**

fuse connected inside a capacitor unit, in series with an element or a group of elements

[IEV 436-03-16]

3.8**line terminal**

terminal intended for connection to a line conductor of a network

[IEV 436-03-01]

NOTE In polyphase capacitors, a terminal intended to be connected to the neutral conductor is not considered to be a line terminal.

3.9**rated capacitance of a capacitor**

C_N

capacitance value derived from the values of rated output, voltage and frequency of the capacitor

[IEV 436-01-12]

3.10**rated output of a capacitor**

Q_N

reactive power for which the capacitor has been designed

[IEV 436-01-16]

3.11**rated voltage of a capacitor**

U_N

r.m.s. value of the alternating voltage for which the capacitor has been designed

[IEV 436-01-15]

NOTE In the case of capacitors consisting of one or more separate circuits (for example single-phase units intended for use in polyphase connection, or polyphase units with separate circuits), U_N refers to the rated voltage of each circuit.

For polyphase capacitors with internal electrical connections between the phases, and for polyphase capacitor banks, U_N refers to the phase-to-phase voltage.

3.12

rated frequency of a capacitor

f_N

frequency for which the capacitor has been designed

[IEV 436-01-14]

3.13

rated current of a capacitor

I_N

r.m.s. value of the alternating current for which the capacitor has been designed

[IEV 436-01-13]

3.14

capacitor losses

active power dissipated in the capacitor

[IEV 436-04-10]

NOTE 1 All loss-producing components should be included, for example:

- for a unit, losses from dielectric, internal fuses, internal discharge resistor, connections, etc;
- for a bank, losses from units, external fuses, busbars, discharge and damping reactors, etc.

NOTE 2 The capacitor losses may be recalculated as an equivalent series resistor to the unit and/or bank.

3.15

tangent of the loss angle (of a capacitor)

$\tan \delta$

ratio between the equivalent series resistance and the capacitive reactance of the capacitor at specified sinusoidal alternating voltage and frequency

[IEV 436-04-11]

3.16

maximum permissible a.c. voltage of a capacitor

maximum r.m.s. alternating voltage which the capacitor can sustain for a given time in specified conditions

[IEV 436-04-07]

3.17

maximum permissible a.c. current of a capacitor

maximum r.m.s. alternating current which the capacitor can sustain for a given time in specified conditions

[IEV 436-04-09]

3.18

ambient air temperature

temperature of the air at the proposed location of the capacitor

3.19

cooling air temperature

temperature of the cooling air measured at the hottest position in the bank, under steady-state conditions, midway between two units

NOTE If only one unit is involved, it is the temperature measured at a point approximately 0,1 m away from the capacitor container and at two-thirds of the height from its base.

3.20**steady-state condition**

thermal equilibrium attained by the capacitor at constant output and at constant ambient air temperature

3.21**residual voltage**

voltage remaining on the terminals of a capacitor at a certain time following disconnection

4 Service conditions**4.1 Normal service conditions**

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

a) Residual voltage at energization

This shall not exceed 10 % of the rated voltage (see Clauses 21 and 31, subclause 19.2 and Annex D).

b) Altitude

This shall not exceed 1 000 m.

c) Ambient air temperature categories

Capacitors are classified in temperature categories, each category being specified by a number followed by a letter. The number represents the lowest ambient air temperature at which the capacitor may operate. The letters represent upper limits of temperature variation ranges, having maximum values specified in Table 1. The temperature categories cover the temperature range of $-50\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$.

The lowest ambient air temperature at which the capacitor may be operated should be chosen from the five preferred values $+5\text{ }^{\circ}\text{C}$, $-5\text{ }^{\circ}\text{C}$, $-25\text{ }^{\circ}\text{C}$, $-40\text{ }^{\circ}\text{C}$, $-50\text{ }^{\circ}\text{C}$.

NOTE With the agreement of the manufacturer, the capacitor may be used at a lower temperature than the limits above, provided that energization takes place at a temperature at or above these limits (see 29.1).

Table 1 is based on service conditions in which the capacitor does not influence the ambient air temperature (for example outdoor installations).

Table 1 – Letter symbols for upper limit of temperature range

Ambient temperature $^{\circ}\text{C}$			
Symbol	Maximum	Highest mean over any period of	
		24 h	1 year
A	40	30	20
B	45	35	25
C	50	40	30
D	55	45	35

NOTE These temperature values can be found in the meteorological temperature tables covering the installation site.

If the capacitor influences the air temperature, the ventilation and/or choice of capacitor shall be such that the Table 1 limits are maintained. The cooling air temperature in such an installation shall not exceed the temperature limits of Table 1 by more than 5 °C.

Any combination of minimum and maximum values can be chosen for the standard temperature category of a capacitor, for example –40/A or –5/C. Preferred standard temperature categories are: –40/A, –25/A, –5/A and –5/C.

4.2 Unusual service conditions

Unless otherwise agreed between manufacturer and purchaser, this standard does not apply to capacitors, the service conditions of which, in general, are incompatible with the requirements of the present standard.

5 Quality requirements and tests

5.1 General

Clauses 5 to 17 gives the test requirements for capacitor units.

Supporting insulators, switches, instrument transformers, external fuses, etc. shall be in accordance with relevant IEC standards.

5.2 Test conditions

Unless otherwise specified for a particular test or measurement, the temperature of the capacitor dielectric shall be in the range +5 °C to +35 °C.

When a correction has to be applied, the reference temperature to be used is +20 °C, unless otherwise agreed between the manufacturer and the purchaser.

It may be assumed that the dielectric temperature of the capacitor unit is the same as the ambient temperature, provided that the capacitor has been left in an unenergized state at a constant ambient temperature for an adequate period.

The a.c. tests and measurements shall be carried out at a frequency of 50 Hz or 60 Hz independent of the rated frequency of the capacitor, if not otherwise specified.

6 Classification of tests

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

6.1 Routine tests

- a) Capacitance measurement (see Clause 7).
- b) Measurement of the tangent of the loss angle ($\tan \delta$) of the capacitor (see Clause 8).
- c) Voltage test between terminals (see Clause 9).
- d) AC voltage test between terminals and container (see Clause 10).
- e) Test of internal discharge device (see Clause 11).
- f) Sealing test (see Clause 12).
- g) Discharge test on internal fuses (see 5.1.1 of IEC 60871-4).

Routine tests shall have been carried out by the manufacturer on every capacitor before delivery. If the purchaser so requests, he shall be supplied with a certificate detailing the results of such tests. The test sequence above is not mandatory.

NOTE If agreed between purchaser and manufacturer, a short-circuit discharge test may be carried out as a routine test. The test parameters should also be agreed upon.

6.2 Type tests

- a) Thermal stability test (see Clause 13).
- b) Measurement of the tangent of the loss angle ($\tan \delta$) of the capacitor at elevated temperature (see Clause 14).
- c) AC voltage test between terminals and container (see Clause 15).
- d) Lightning impulse voltage test between terminals and container (see Clause 16).
- e) Short-circuit discharge test (see Clause 17).
- f) Test of an external fuse in combination with a capacitor (see Annex C).
- g) Disconnecting test on internal fuses (see 5.3 of IEC 60871-4).

Type tests are carried out in order to ascertain that, as regards design, size, materials and manufacture, the capacitor complies with the characteristics and operational requirements specified in this standard.

Unless otherwise specified, every capacitor sample to which it is intended to apply the type test shall first have withstood satisfactorily the application of all the routine tests.

The type tests shall be made upon capacitors of a design identical with that of the capacitor to be supplied or on capacitors of design and processing that do not differ from it in any way that might influence the properties to be checked by the type test.

It is not essential that all type tests be carried out on the same capacitor unit, they may be carried out on different units having the same characteristics.

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

6.3 Acceptance tests

The routine and/or type tests, or some of them, may be repeated by the manufacturer in connection with any contract by agreement with the purchaser.

The number of samples that may be subjected to such tests, and the acceptance criteria, shall be subject to agreement between manufacturer and purchaser, and shall be stated in the contract.

6.4 Endurance test (special test)

The endurance test is a test on elements (their dielectric design and composition), and on the manufacturing process of these elements when assembled in a capacitor unit. An endurance test, which is both time-consuming and expensive, covers a range of capacitor designs (see IEC 60871-2).

7 Capacitance measurement (routine test)

7.1 Measuring procedure

The capacitance shall be measured at 0,9 to 1,1 times the rated voltage, using a method that excludes errors due to harmonics.

Measurement at another voltage is permitted, provided that appropriate correction factors are agreed upon between the manufacturer and the purchaser.

The final capacitance measurement shall be carried out after the voltage test (see Clauses 9 and 10).

In order to reveal any change in capacitance, for example due to puncture of an element, or failure of an internal fuse, a preliminary capacitance measurement shall be made, before the other electrical routine tests. This preliminary measurement shall be performed with a reduced voltage not higher than $0,15 U_N$.

The accuracy of the measuring method shall be such that the tolerances according to 7.2 can be met. If agreed upon, a higher accuracy may be required, and, in such a case, the accuracy of the measuring method shall be stated by the manufacturer.

The repeatability of the measuring method shall be such that a punctured element or an operated internal fuse can be detected.

NOTE For polyphase capacitors, the measuring voltage should be adjusted to give 0,9 to 1,1 times rated voltage across each element.

7.2 Capacitance tolerances

The capacitance shall not differ from the rated capacitance by more than

- 5 % to +10 % for capacitor units,
- 5 % to +10 % for banks up to 3 Mvar total rating,
- 0 % to +10 % for banks from 3 Mvar to 30 Mvar total rating,
- 0 % to +5 % for banks above 30 Mvar total rating.

The capacitance value is that measured under the conditions of 7.1.

In three-phase units and banks, the ratio of maximum to minimum values of capacitance measured between any two line terminals shall not exceed 1,08.

NOTE 1 See also 31.5 concerning tolerances.

NOTE 2 A formula for the calculation of the output of a three-phase capacitor from single-phase capacitance measurements is given in Annex D.

NOTE 3 For banks above 3 Mvar total rating, closer tolerances for output and phase capacitance ratios may be agreed between manufacturer and purchaser.

NOTE 4 Smaller ratios of maximum to minimum value of the phase capacitances may be needed in star-connected banks with isolated neutral (see 31.5).

8 Measurement of the tangent of the loss angle ($\tan \delta$) of the capacitor (routine test)

8.1 Measuring procedure

The capacitor losses ($\tan \delta$) shall be measured at 0,9 to 1,1 times rated voltage, using a method that excludes errors due to harmonics. The accuracy of the measuring method and the correlation with the values measured at rated voltage and frequency shall be given.

NOTE 1 For polyphase capacitors, the measuring voltage should be adjusted to give 0,9 to 1,1 times rated voltage across each element.

NOTE 2 The tangent of loss angle of impregnated low-loss dielectrics decreases during the first hours of initial energization. This decrease is not correlated to the $\tan \delta$ variation with temperature. The $\tan \delta$ measured in routine testing may vary significantly between identical units manufactured simultaneously. The final "stabilized" values are, however, usually within close limits, as indicated by differences recorded between routine test measurements and the value found in thermal stability testing or alternative methods for conditioning according to manufacturer's practice.

NOTE 3 The measuring equipment should be calibrated according to IEC 60996 or to another method that will give the same or an improved accuracy.

8.2 Loss requirements

The requirements regarding capacitor losses shall be agreed upon between manufacturer and purchaser.

The value of capacitor losses is that measured under the conditions of 8.1.

8.3 Losses in external fuses

Losses in external fuses shall be calculated using the nominal a.c. resistance (specified by the fuse manufacturer at 20 °C) times the square of rated capacitor current.

9 Voltage test between terminals (routine test)

Every capacitor shall be subjected for 10 s to either the test of 9.1 or that of 9.2. In the absence of an agreement, the choice is left to the manufacturer. During the test, neither puncture nor flashover shall occur.

9.1 AC test

The a.c. test shall be carried out with a substantially sinusoidal voltage:

$$U_t = 2,0 U_N$$

NOTE 1 If the capacitors are to be re-tested after delivery a voltage of 75 % of U_t is recommended for the second test.

NOTE 2 For polyphase capacitors, the test voltage should be adjusted to give the appropriate voltage across each element.

NOTE 3 Units having internal element fuses, and within the capacitance tolerances in spite of one or more operated element fuses, may only be delivered after agreement between purchaser and manufacturer.

9.2 DC test

The test voltage shall be as follows:

$$U_t = 4,0 U_N$$

NOTE 1 See 9.1, Note 1.

NOTE 2 See 9.1, Note 2.

NOTE 3 See 9.1, Note 3.

10 AC voltage test between terminals and container (routine test)

Capacitor units having all terminals insulated from the container shall be subjected for 10 s to a test voltage applied between the terminals (joined together) and the container.

For units used in banks with isolated neutral, and with the containers connected to ground, test voltages according to 18.1 shall apply. For all other bank connections the test voltage is proportional to the rated voltage and calculated according to 18.3.

If it is not known whether a unit with terminals insulated from the container will be used with the container connected to ground or not, test voltages according to 18.1 shall apply. The purchaser shall specify if the test is required.

Units having one terminal permanently connected to the container shall not be subjected to this test.

Units with separate phases shall be subjected to voltage tests between phases of the same value as for the terminals to container test.

During the test, neither puncture nor flashover shall occur.

11 Test of internal discharge device (routine test)

The resistance of the internal discharge device, if any, shall be checked by a resistance measurement (see Clause 21 and Annex D).

The choice of the method is left to the manufacturer.

The test shall be made after the voltage test of Clause 9.

12 Sealing test (routine test)

The unit (in non-painted state) shall be exposed to a test that will effectively detect any leak of the container and bushing(s). The test procedure is left to the manufacturer, who shall describe the test method concerned.

If no procedure is stated by the manufacturer, the following test procedure shall apply. Unenergized capacitor units shall be heated throughout for at least 2 h, so that all parts reach a temperature not lower than 20 °C above the maximum value in Table 1. No leakage shall occur. It is recommended that a suitable indicator is used.