IEC TS 60871-2

Edition 3.1 2022-03
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

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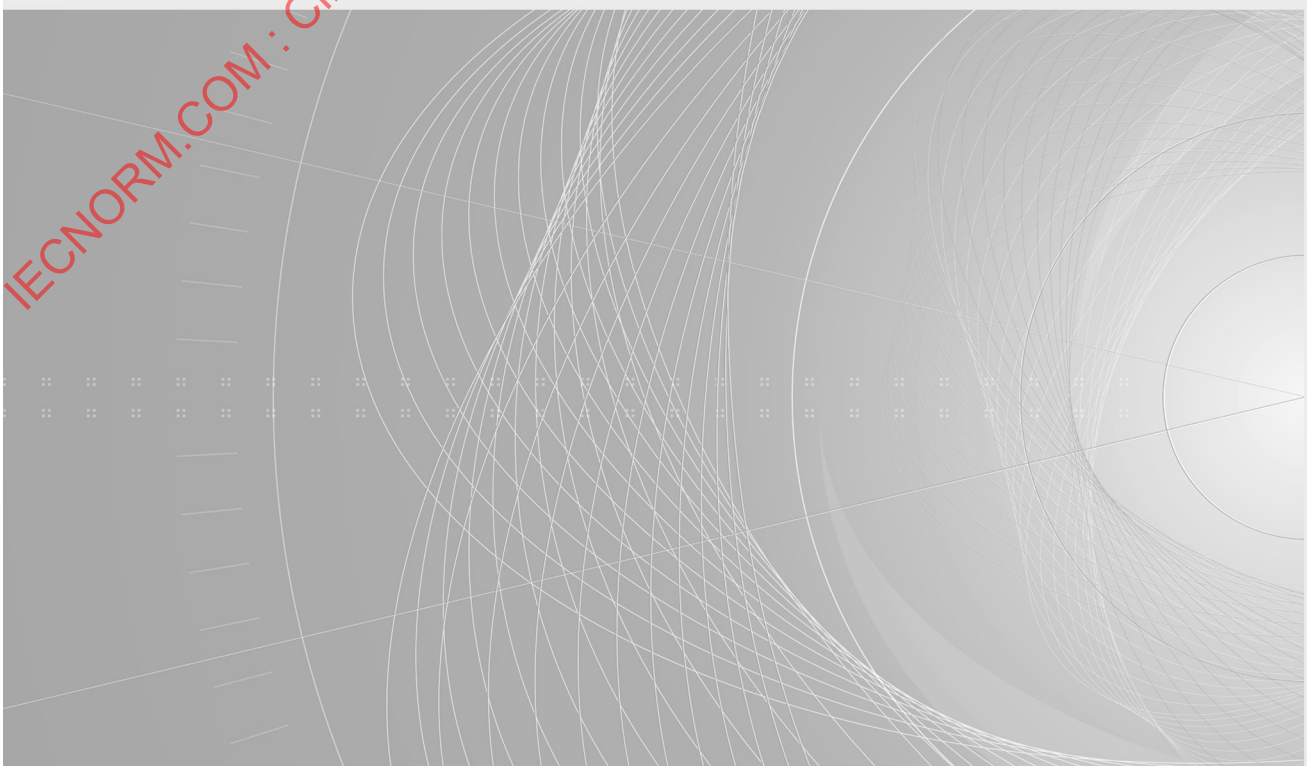
Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 2: Endurance testing



IEC TS 60871-2:2014-11+AMD1:2022-03 CSV(en)

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INTERNATIONAL STANDARD

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Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 2: Endurance testing

INTERNATIONAL
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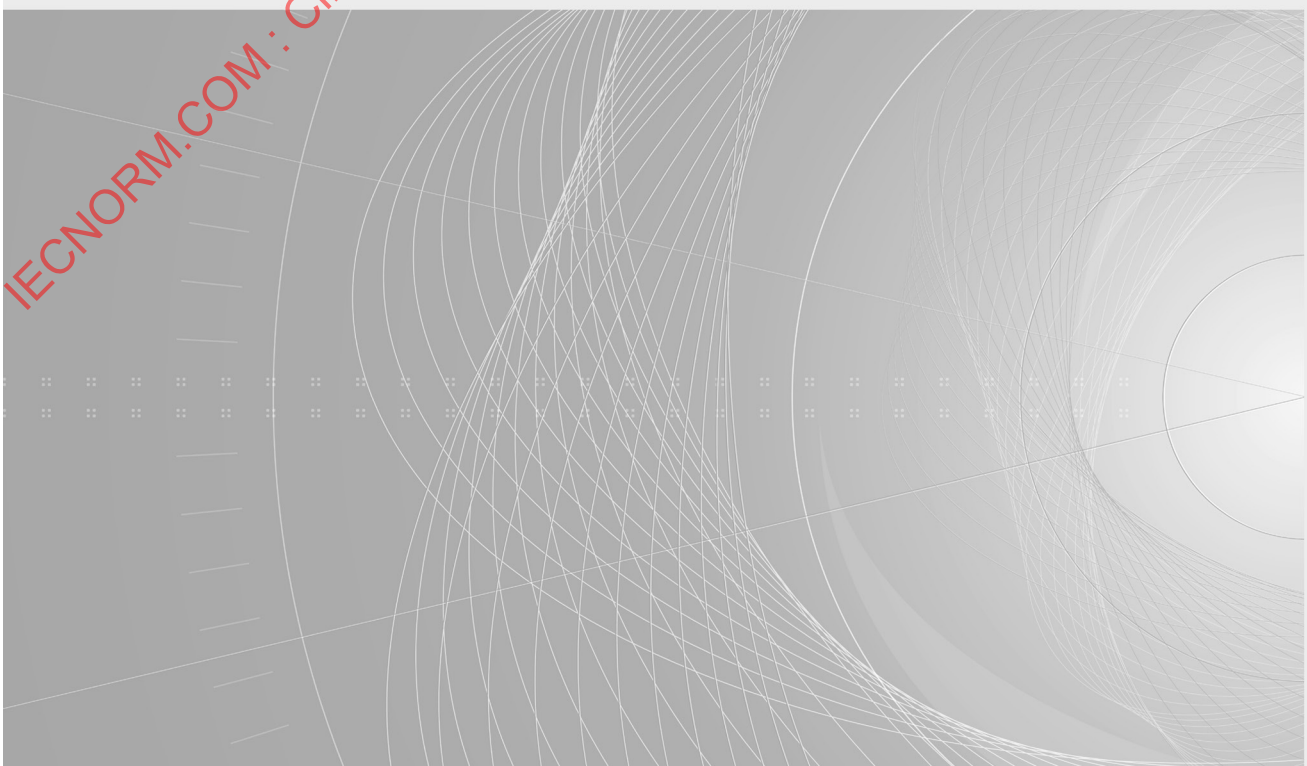

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 2: Endurance testing

FOREWORD

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC TS 60871-2 edition 3.1 contains the third edition (2014-11) [documents 33/536/DTS and 33/565/RVC] and its amendment 1 (2022-03) [documents 33/668/DTS and 33/671/RVDTS].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 60871-2, which is a technical specification, has been prepared by IEC technical committee 33: Power capacitors and their applications.

This third edition constitutes a technical revision.

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

a) The overvoltage cycling test has been moved to IEC 60871-1:2014.

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

A list of all parts in the IEC 60871 series, published under the general title *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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SHUNT CAPACITORS FOR AC POWER SYSTEMS HAVING A RATED VOLTAGE ABOVE 1 000 V –

Part 2: Endurance testing

1 Scope

This part of IEC 60871, which is a technical specification, applies to capacitors according to IEC 60871-1 and gives the requirements for ageing tests of these capacitors.

2 Normative references

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

IEC 60871-1:2014, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 1: General*

IEC TR 60996, *Method for verifying accuracy of tan delta measurements applicable to capacitors*

3 Terms and definitions

For the purpose of this technical specification, the following terms and definitions apply in addition to those given in IEC 60871-1:

3.1
test unit
one of the units to be manufactured or a special unit which, with respect to the properties to be checked by the ageing test, is equivalent to the units to be manufactured

Note 1 to entry: The restrictions on test unit design are detailed in Annex A.

3.2
comparable element design
range of construction elements that will be comparable in performance, under the test procedure, with elements of the units to be manufactured

Note 1 to entry: See Annex A for detailed design limits.

3.3
inter-element insulation
insulation between two series-connected elements, consisting of:

– the outer turns of the insulation layers around the electrodes in an element, or
– a separate insulation layer placed between the two elements

Note 1 to entry: This separate insulation layer may protrude outside the width and (or) length dimension(s) of the flattened element (see Annex B).

4 Quality requirements and tests

4.1 Test requirements – General purpose

The ageing test is a special test carried out in order to ascertain that the progression of deterioration resulting from increased voltage stress at elevated temperature does not cause untimely failure of the dielectric. It is a mean to ensure that basic material selection is properly made and that any rapid deterioration does not take place. The test should not be seen as a tool for any exact assessment of life characteristics of a dielectric. For that purpose various research and development activities are to be taken care of by the manufacturers.

The ageing test shall be carried out as special tests by the manufacturer for a particular dielectric system, i.e. not for each particular capacitor rating. The test results are applicable to a wide range of capacitor ratings within the limits defined in Annex A. The purchaser shall, on request, be supplied with a certificate detailing the results of such tests.

4.2 Test procedure

4.2.1 General

The ageing test shall be carried out in the sequence given below. The applied test voltage shall have a frequency of 50 Hz or 60 Hz, except for the test according to 4.2.2 where a d.c. voltage can be used according to 9.3 of IEC 60871-1:2014.

4.2.2 Routine test

The test unit shall be subjected to the routine voltage test between the terminals (see IEC 60871-1) with an amplitude such that the correct test voltage is obtained across each element.

4.2.3 Conditioning of the units before the test

The test unit shall be subjected to a voltage of not less than 1,1 U_N at an ambient temperature of not less than +10 °C for not less than 16 h.

NOTE The conditioning is carried out to stabilize the dielectric properties of the test units.

4.3 Ageing test

4.3.1 Initial capacitance and dielectric loss measurements

The capacitor unit shall be measured at 0,9 to 1,1 times the rated voltage. The choice of temperature is left to the manufacturer.

4.3.1.1 Test method

The ambient temperature during the ageing test shall be not less than 55 °C.

It is anticipated, given the limits for the test object specified in Annex A, that more than 60 °C average dielectric temperature is achieved. If requested by the purchaser further details about the relation between external and internal (dielectric) temperatures should be given by the manufacturer. The dielectric temperature may be measured with thermocouples on specially prepared test units or estimated from previously established relationships between internal and external temperatures such as by use of resistive dummy capacitors described in IEC 60996.

The ambient temperature shall be held constant with a tolerance of –2 °C to +5 °C. Prior to energization, the test units shall be stabilized in this ambient for 12 h. Due to the length of this test, voltage interruptions are allowed. During these interruptions, the units shall remain in the

controlled ambient. If power is lost to the chamber, the ambient temperature shall be reattained for 12 h prior to re-energization of the units.

The testing time shall depend on the test voltage. Either one of the following test conditions shall be used:

Test voltage	Duration h
1,25 U_N	3 000
1,40 U_N	1 000

4.3.2 Final capacitance and dielectric loss measurements

The measurement shall be repeated under the same conditions as for the initial measurement, within a temperature tolerance of ±5°C. The measurements shall be made within two days after completing the tests in 4.1.3.2.

4.3.3 Acceptance criteria

No breakdown shall occur when two units have been tested, or alternatively one breakdown is accepted when three units have been tested.

To verify no breakdown the capacitance measurements performed in 4.3.1 and 4.3.2 shall differ by less than an amount corresponding to breakdown of an element.

4.4 Validity of test

The ageing test is a test on the elements (their dielectric design and composition), and on their processing (element winding, drying and impregnation) when assembled in a capacitor unit. Each ageing test will also cover other capacitor designs, which are allowed to differ from the tested design within the limits stated in Annex A.

A test performed at 50 Hz is also applicable for 60 Hz (and lower frequency) units and vice versa.

5 Element fail safe test for fuseless capacitors

5.1 General

The proof of element fail safe is a design test applicable to fuseless power capacitors, as defined in IEC 60871-1:2014, Clause E.4.

This proof is obtained by means of two separate tests, the low energy test and the high energy test.

The low energy test is aimed to demonstrate that a failure of one capacitive element, caused by a low voltage element failure event at the rated voltage, will result in reliable and secure foil welding on the failed portion of the element without generation of hot spots and persistent release of gas.

The high energy test is aimed to demonstrate that a failure of one or more capacitive elements, caused by the occurrence of an overvoltage on the capacitor bank, will result in reliable and safe behaviour without container rupture or explosion.

The physical location of the fault on the capacitor element is intended to represent the worst possible location under the expected low or high energy level tested. A damage to the

insulation of the container is acceptable, provided that it maintains enough insulation in order to remain in service until replacement.

5.2 Test unit

5.2.1 General

Two set-ups of the test unit are possible, as described in 5.2.2 and 5.2.3; the manufacturer shall choose the set-up and manufacture the test unit accordingly.

5.2.2 Set-up of the test unit, first method

The test unit shall be a capacitor unit comparable to the units to be manufactured, as described in Annex A, with the following features:

- The container shall be identical to that used for the units to be manufactured.
- The test unit shall contain a single active element, i.e. electrically connected to the bushings for power supply; the other elements shall be passive, i.e. not electrically connected neither to the active element nor to the bushings.
- The unit may be equipped with some means of shorting the capacitor terminals, such as metallic wires between terminals, for safe handling.
- The position of the tested element shall be located at the top location nearest to the bushing lid.
- The element shall be of the same size to that used for the units to be manufactured.

Each test shall be conducted on a separate test unit, differing for the intentional damage of the active element (as described in 5.2.4 to 5.2.5) but otherwise identical.

5.2.3 Set-up of the test unit, second method

The test unit shall be a capacitor unit comparable to the units to be manufactured, as described in Annex A, with the following features:

- The container shall be identical to that used for the units to be manufactured.
- The test unit shall have full-size active elements, with only one pre-damaged active element identical to those included in the capacitor unit supplied.
- The unit may be equipped with some means of shorting the capacitor terminals, such as metallic wires between terminals, for safe handling.
- The position of the tested element shall be located at the top location nearest to the bushing lid.
- The capacitor units shall be constructed with appropriate resistor values capable to withstand high voltage (see 5.3).

5.2.4 Active element for the low energy test

The insulating films between the two active electrodes of the element for the low energy test shall be mechanically damaged before insertion in the test unit, in order facilitate the element failure during the low energy test.

The mechanical damage shall be located at 5 ± 1 cm from the margin of the element and roughly on the fringe of the element's length as shown in Figure 1. The damage shall be located between five and ten plies from the outermost ply of the element. Two dielectric layers between consecutive metallic foils shall be separately punctured; the punctures should be sufficiently apart in order to avoid shorting the element just at the beginning of the test.

NOTE It is suggested to puncture the layers using a heated nail of about 2 mm in diameter.

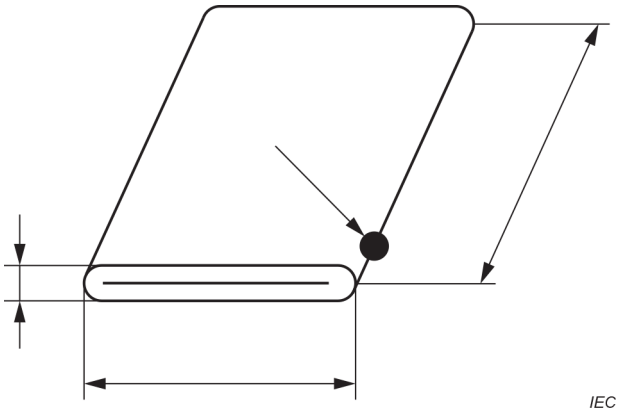

Figure 1 – Puncture location on the active element

5.2.5 Active element for the high energy test

One of the insulating films between the two active electrodes of the active element shall be mechanically damaged during manufacturing in a manner to facilitate the element failure at the time of the tests.

The mechanical damage shall be located at 5 ± 1 cm from the margin of the element and roughly on the fringe of the element's length as shown in Figure 1. The damage shall be located between five and ten plies from the outermost ply of the element. Only one dielectric layer between consecutive metallic foils shall be punctured.

NOTE It is suggested to puncture the layer using a heated nail of about 2 mm in diameter.

5.3 Conditioning of the unit

5.3.1 General

Two methods to prepare the test circuit are possible, as described in 5.3.2 and 5.3.3; the manufacturer shall choose the method and prepare the test circuit accordingly.

5.3.2 Circuit for achieving a failed test unit, first method

The electrical failure of each test unit shall be produced by the discharge of a pre-charged loading capacitor unit in parallel to the test unit. The suggested electric circuit is shown in Figure 2.

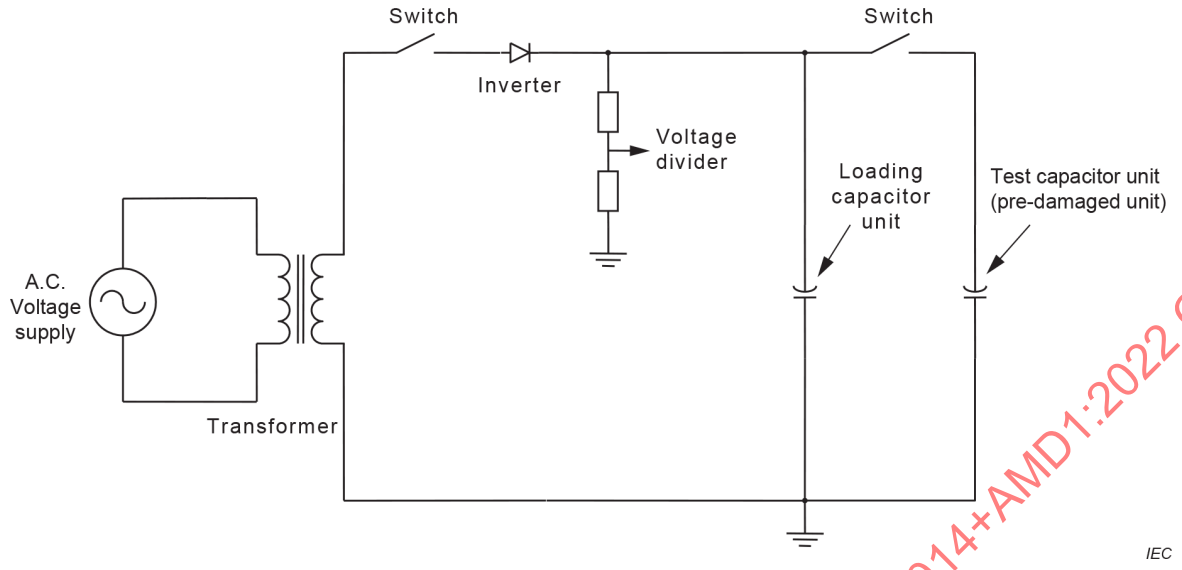

Figure 2 – Electric circuit for conditioning of the units

The discharge into the active element shall be performed by closing the switch in the branch of the test unit, while disconnecting the power supply. Voltage and current shall be recorded during this capacitive discharge to verify that the desired voltage level and the discharge are achieved. Multiple discharges may be necessary for failure to occur. The test unit shall be fully and safely discharged between attempts.

NOTE The use of a shorting stick is suggested, where applicable, in order to shorten the discharge time.

5.3.3 Circuit for achieving a failed test unit, second method

The unit shall be equipped with a modified discharge resistor in order to overheat it to failure. A preheating of the unit at 80 °C for 12 hours with the regular resistor is also possible to achieve a similar result.

NOTE The modified discharge resistor is preferably located near the tested element, in order to focalize the heat to the targeted element and not to the other healthy elements.

The electrical failure of the test units shall be produced by applying and maintaining a DC voltage corresponding to the required energy level for at least 30 minutes or until the element fails.

The applied DC voltage, combined with the heating produced by the modified discharge resistor, should create the proper condition to initiate the element failure. Voltage and current shall be recorded during this attempt to verify that the desired energy level is achieved. Multiple attempts may be necessary for failure to occur. The test units shall be fully discharged between attempts.

For a high energy test unit, a short circuit of the test unit at nominal voltage may be performed between attempts to weaken the tested element, if the attempt exceeds 30 minutes.

5.3.4 Failure of the unit for the low energy test

The failure of the unit for the low energy test is meant to represent the failure of a capacitor element with a low level of stored energy. The loading capacitor shall be pre-charged to a voltage level that does not result in a stored parallel energy higher than the one available to a single element as part of a complete unit when the applied voltage is equal to $0{,}9 \times \sqrt{2} \times U_N$. A tolerance in the range from 0 to +10 % on the test voltage is considered acceptable.

5.3.5 Failure of the unit for the high energy test

The failure of the unit for the high energy test is meant to represent the failure of a capacitor element with a high level of stored energy. The loading capacitor shall be pre-charged to a voltage level that does not result in a stored parallel energy lower than the one available to a single element as part of a complete unit when the applied voltage is equal to 3,0 × $\sqrt{2}$ × U_N. A tolerance in the range from -10 % to 0 on the test voltage is considered acceptable.

NOTE The voltage level is chosen to represent a restrike on the circuit breaker during the opening of the capacitor bank.

5.4 Test procedure

5.4.1 General

The following test procedure is applicable for both the low and high energy tests.

5.4.2 Discharge test

A discharge test in accordance with Clause 17 of IEC 60871-1:2014 shall be performed on each of the previously failed test units. The desired discharge current shall be calculated based on the ratio of the number of parallel elements in a complete unit and the total current which would result from discharging that complete unit.

The test unit shall be connected in series with a healthy unit which was previously pre-charged with the DC voltage necessary to obtain the desired discharge current. Figure 3 shows the suggested test setup.

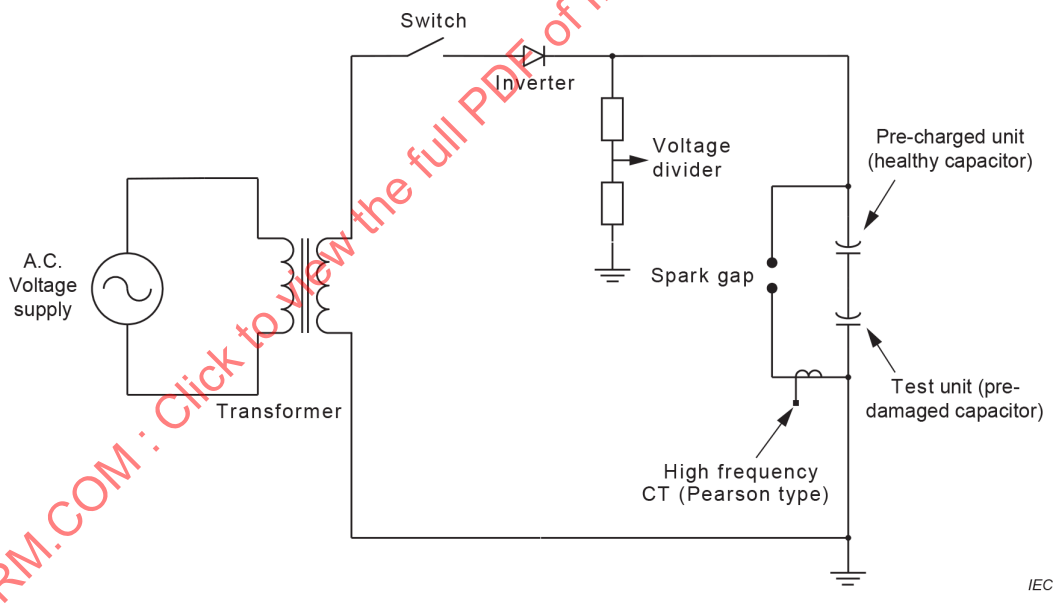

Figure 3 – Electric circuit for the discharge test

5.4.3 Load current test

After subjecting the unit to the discharge test, it shall be placed into a cold chamber at the lowest rated ambient temperature for a period of at least 12 hours. Within five minutes following their removal from the cold chamber, units shall be energized with a current that would circulate if the designed standard unit would have one element shorted at ambient temperature (20 ± 5 °C) and subjected to 1,1 × U_N.

Four temperature sensors shall be placed on the capacitor container, one at the failure location and three at different locations away from the failure.

NOTE It is suggested to place the three sensors near the bottom of the unit.

The test current shall be maintained for a period of 48 hours or until the temperature increase, as measure by the average of the temperature sensors, stabilize to an increase less than 1 K/h for a period of at least five thermal time constants of the unit. Figure 4 shows the suggested test setup.

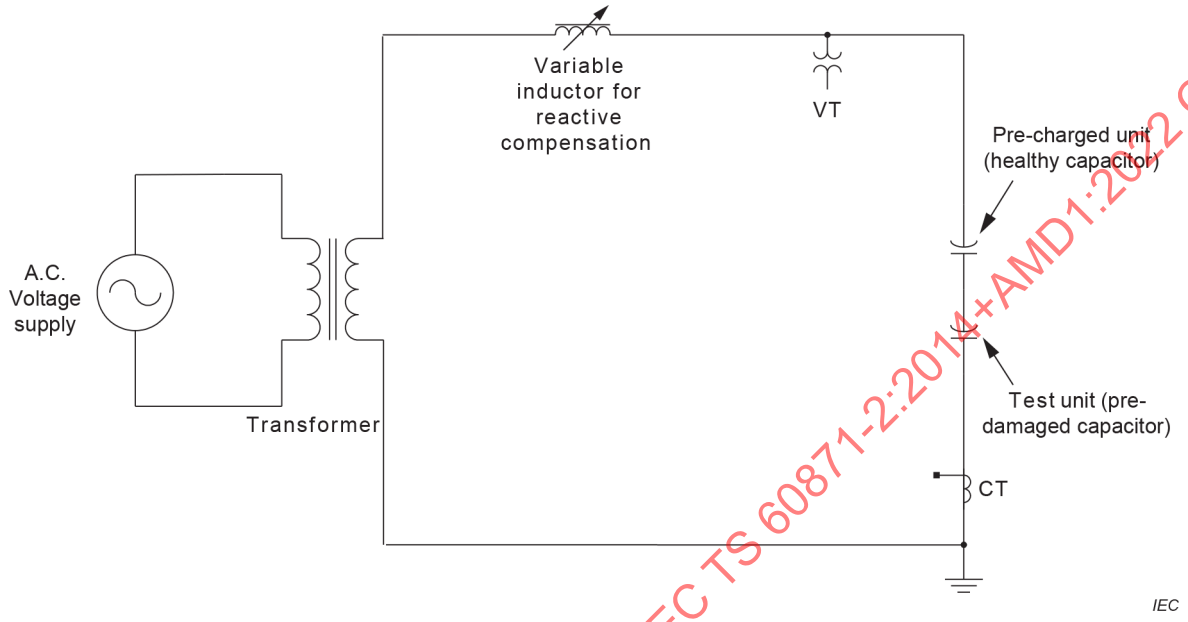

Figure 4 – Electric circuit for the load current test

5.4.4 AC voltage test between terminals and container

The AC voltage test between terminals and container, as described in 15.1 and Clause 18 of IEC 60871-1:2014, shall be performed at 80 % of the test voltage intended for this design, as defined in IEC 60871-1. The duration of the test shall be 60 seconds.

5.5 Success criteria

The test of each unit shall be deemed successful if the following criteria are respected:

a) The discharge test, the load current test and AC voltage test between terminals and container are passed.

b) The container remains sealed; deformations are allowed but no rupture is permitted.

c) The welding of the failed element presents a good electrical and mechanical connection at a visual inspection; burned insulation layers near the location of the punctures are allowed, provided that the units passed the AC voltage test.

d) The difference, recorded at the end of the load current test, between the temperature at failure location and the average of the temperatures recorded at the three other locations is equal or less than 10 K.

The proof of element fail safe is obtained if both the low energy and high energy test units meet the success criteria.

Annex A
(normative)

Requirements regarding comparable element design and test unit design

A.1 Test element design criteria

A tested element design is considered to be comparable with respect to the elements in the units to be manufactured if the following requirements are fulfilled:

a) the tested element shall have the same or an inferior number of layers of solid materials in the dielectric and be impregnated with the same liquid.

   the dielectric shall be within 70°% to 130°% of the thickness and be rated at equal or higher electrical stress.

   when a dielectric contains both film and paper, the stress value to be used in this comparison is the stress across each of the solid materials, calculated using the thickness of only the solid materials and their respective permittivity.

   for the ageing test, using resistors and/or internal fuses is irrelevant for the test. It is up to the manufacturer to choose.

b) the dielectric composition of the solid materials shall be the same, for example all-film or all-paper or film-paper-film, etc.;

c) solid and liquid dielectric materials shall satisfy the same manufacturer's specifications;

d) the aluminium-foil design shall be the same:
   - same manufacturer's specification;
   - thickness within ±20 %;
   - extended or non-extended foil edges;
   - folded foil at the edges and (or) cut ends if it is a feature of the design;
   - less or equal free margin;

e) element connections shall be of the same type, for example tabs, soldering, etc.;

f) the element width (active foil width) is allowed to vary within 50°% to 400°% and the element length (active foil length) is allowed to vary within 30°% to 300°% (see Annex B).

A.2 Test unit design

A test unit is considered to be comparable to the units to be manufactured if the following requirements are satisfied:

a) elements meeting the requirements of Clause A.1 shall be similarly assembled, have equal or thinner inter-element insulation, be equally pressed within the manufacturing tolerance, etc., as compared with the units to be manufactured;

b) a suitable number of elements shall be connected to give not less than 100 kvar output at rated voltage (50 Hz). All connected elements shall be placed adjacent to each other.

   NOTE The connected elements may be series and parallel-connected in any way to match the test equipment.

c) the connections outside the tested elements may be enlarged in order to handle the increased currents due, for example, to a number of elements in parallel;

d) the insulation to the container shall be of the same thickness or thicker;

   NOTE This requirement is intended to ensure that the drying and impregnation conditions are equal to those of the units to be produced. The electrical withstand requirements of the insulation to container are taken care of by the tests according to Clauses 10 and 15 of IEC 60871-1:2014.

e) a container shall be used, the height of which is not less than 20% of the height of the unit to be manufactured. The depth and width of the container shall not be less than 50%.

NOTE These ranges in container dimensions are necessary to allow for the variation in element sizes.

The container material shall be of equal type (metal, polymer etc.), but the painting can be omitted or may be different.

The bushing design and number of bushings may be adjusted in order to match the test voltage and/or test currents;

f) the drying and impregnation process shall be identical with the normal production process.

Annex B
(informative)

Definition of element and capacitor container dimensions

B.1 Flattened pressed element

As shown in Figure B.1, the element has been pressed flat in the height direction.

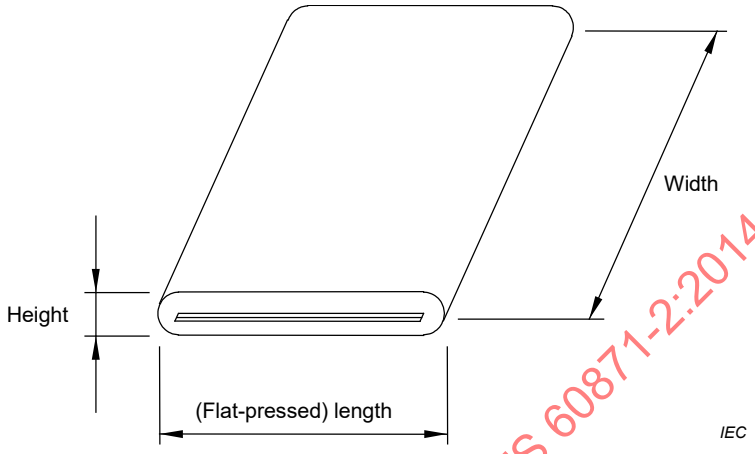

Figure B.1 – Flattened pressed element

Element or (active) foil length is obtained by unwinding the element in the length direction.

B.2 Capacitor container

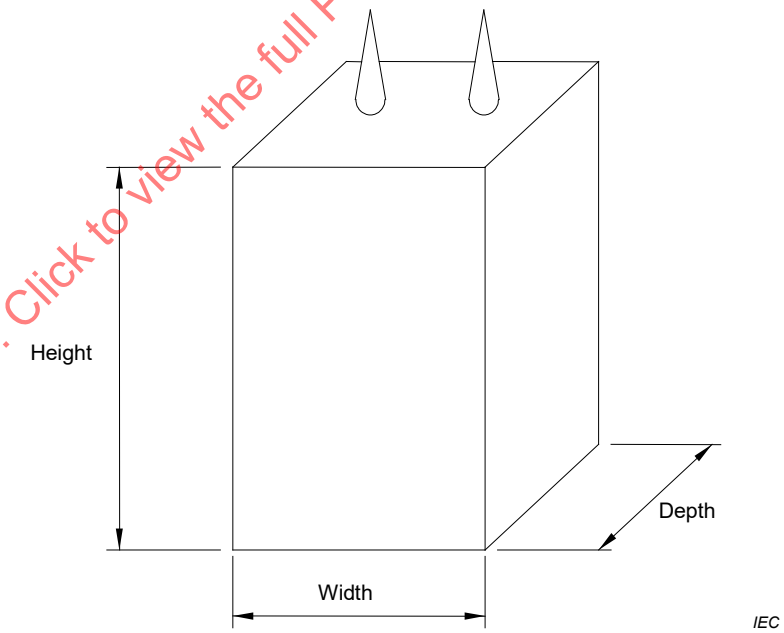

Figure B.2 – Capacitor container

Height is always determined from the side on which the bushings are fitted to the opposite side. Normally the length dimension of the flattened element corresponds to the container depth dimension. Depending on the design, the element width direction may correspond to either the container height or the container width dimension (see Figure B.2).

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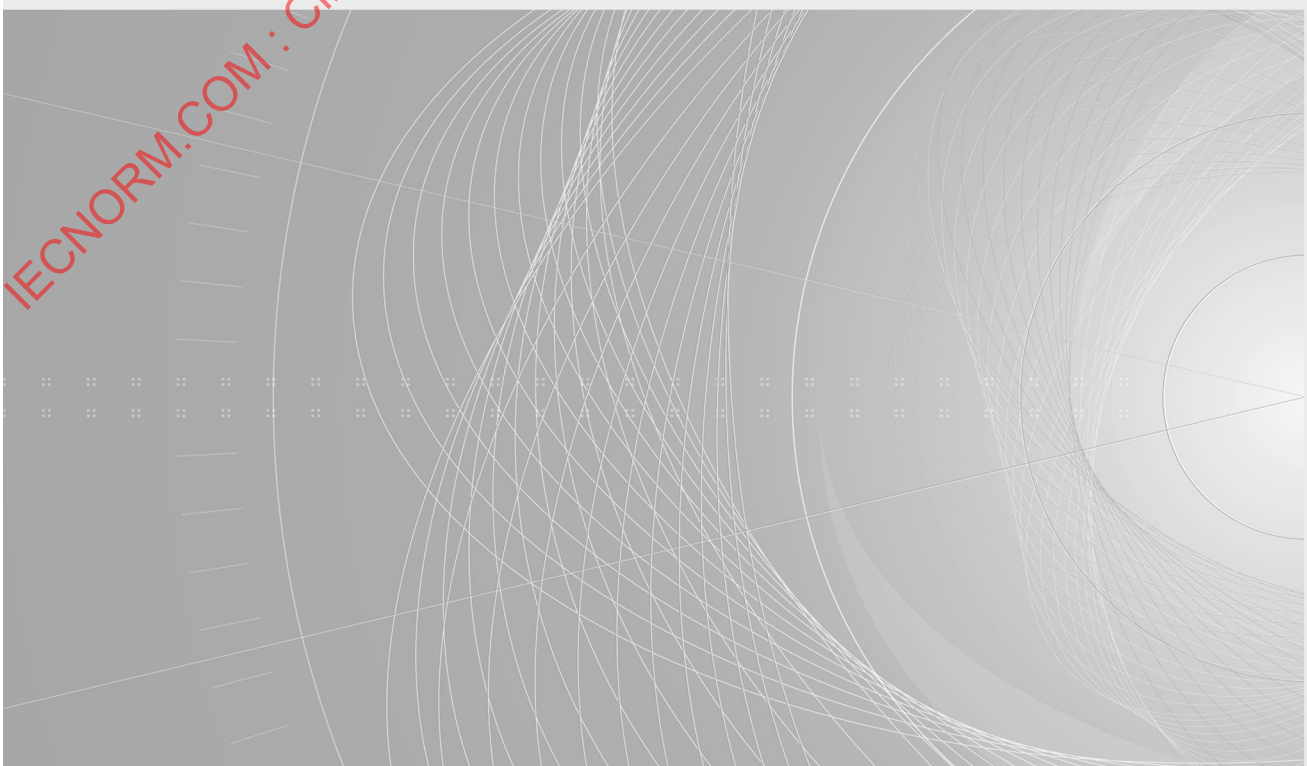

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SHUNT CAPACITORS FOR AC POWER SYSTEMS HAVING A RATED VOLTAGE ABOVE 1 000 V –

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC TS 60871-2 edition 3.1 contains the third edition (2014-11) [documents 33/536/DTS and 33/565/RVC] and its amendment 1 (2022-03) [documents 33/668/DTS and 33/671/RVDTS].

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 60871-2, which is a technical specification, has been prepared by IEC technical committee 33: Power capacitors and their applications.

This third edition constitutes a technical revision.

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

a) The overvoltage cycling test has been moved to IEC 60871-1:2014.

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

A list of all parts in the IEC 60871 series, published under the general title *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

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

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

Part 2: Endurance testing

1 Scope

This part of IEC 60871, which is a technical specification, applies to capacitors according to IEC 60871-1 and gives the requirements for ageing tests of these capacitors.

2 Normative references

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

IEC 60871-1:2014, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 1: General*

IEC TR 60996, *Method for verifying accuracy of tan delta measurements applicable to capacitors*

3 Terms and definitions

For the purpose of this technical specification, the following terms and definitions apply in addition to those given in IEC 60871-1:

3.1
test unit
one of the units to be manufactured or a special unit which, with respect to the properties to be checked by the ageing test, is equivalent to the units to be manufactured

Note 1 to entry: The restrictions on test unit design are detailed in Annex A.

3.2
comparable element design
range of construction elements that will be comparable in performance, under the test procedure, with elements of the units to be manufactured

Note 1 to entry: See Annex A for detailed design limits.

3.3
inter-element insulation
insulation between two series-connected elements, consisting of:

– the outer turns of the insulation layers around the electrodes in an element, or
– a separate insulation layer placed between the two elements

Note 1 to entry: This separate insulation layer may protrude outside the width and (or) length dimension(s) of the flattened element (see Annex B).

4 Quality requirements and tests

4.1 Test requirements – General purpose

The ageing test is a special test carried out in order to ascertain that the progression of deterioration resulting from increased voltage stress at elevated temperature does not cause untimely failure of the dielectric. It is a mean to ensure that basic material selection is properly made and that any rapid deterioration does not take place. The test should not be seen as a tool for any exact assessment of life characteristics of a dielectric. For that purpose various research and development activities are to be taken care of by the manufacturers.

The ageing test shall be carried out as special tests by the manufacturer for a particular dielectric system, i.e. not for each particular capacitor rating. The test results are applicable to a wide range of capacitor ratings within the limits defined in Annex A. The purchaser shall, on request, be supplied with a certificate detailing the results of such tests.

4.2 Test procedure

4.2.1 General

The ageing test shall be carried out in the sequence given below. The applied test voltage shall have a frequency of 50 Hz or 60 Hz, except for the test according to 4.2.2 where a d.c. voltage can be used according to 9.3 of IEC 60871-1:2014.

4.2.2 Routine test

The test unit shall be subjected to the routine voltage test between the terminals (see IEC 60871-1) with an amplitude such that the correct test voltage is obtained across each element.

4.2.3 Conditioning of the units before the test

The test unit shall be subjected to a voltage of not less than 1,1 U_N at an ambient temperature of not less than +10 °C for not less than 16 h.

NOTE The conditioning is carried out to stabilize the dielectric properties of the test units.

4.3 Ageing test

4.3.1 Initial capacitance and dielectric loss measurements

The capacitor unit shall be measured at 0,9 to 1,1 times the rated voltage. The choice of temperature is left to the manufacturer.

4.3.1.1 Test method

The ambient temperature during the ageing test shall be not less than 55 °C.

It is anticipated, given the limits for the test object specified in Annex A, that more than 60 °C average dielectric temperature is achieved. If requested by the purchaser further details about the relation between external and internal (dielectric) temperatures should be given by the manufacturer. The dielectric temperature may be measured with thermocouples on specially prepared test units or estimated from previously established relationships between internal and external temperatures such as by use of resistive dummy capacitors described in IEC 60996.

The ambient temperature shall be held constant with a tolerance of –2 °C to +5 °C. Prior to energization, the test units shall be stabilized in this ambient for 12 h. Due to the length of this test, voltage interruptions are allowed. During these interruptions, the units shall remain in the

controlled ambient. If power is lost to the chamber, the ambient temperature shall be reattained for 12 h prior to re-energization of the units.

The testing time shall depend on the test voltage. Either one of the following test conditions shall be used:

Test voltage	Duration h
1,25 U_N	3 000
1,40 U_N	1 000

4.3.2 Final capacitance and dielectric loss measurements

The measurement shall be repeated under the same conditions as for the initial measurement, within a temperature tolerance of ±5°C. The measurements shall be made within two days after completing the tests in 4.1.3.2.

4.3.3 Acceptance criteria

No breakdown shall occur when two units have been tested, or alternatively one breakdown is accepted when three units have been tested.

To verify no breakdown the capacitance measurements performed in 4.3.1 and 4.3.2 shall differ by less than an amount corresponding to breakdown of an element.

4.4 Validity of test

The ageing test is a test on the elements (their dielectric design and composition), and on their processing (element winding, drying and impregnation) when assembled in a capacitor unit. Each ageing test will also cover other capacitor designs, which are allowed to differ from the tested design within the limits stated in Annex A.

A test performed at 50 Hz is also applicable for 60 Hz (and lower frequency) units and vice versa.

5 Element fail safe test for fuseless capacitors

5.1 General

The proof of element fail safe is a design test applicable to fuseless power capacitors, as defined in IEC 60871-1:2014, Clause E.4.

This proof is obtained by means of two separate tests, the low energy test and the high energy test.

The low energy test is aimed to demonstrate that a failure of one capacitive element, caused by a low voltage element failure event at the rated voltage, will result in reliable and secure foil welding on the failed portion of the element without generation of hot spots and persistent release of gas.

The high energy test is aimed to demonstrate that a failure of one or more capacitive elements, caused by the occurrence of an overvoltage on the capacitor bank, will result in reliable and safe behaviour without container rupture or explosion.

The physical location of the fault on the capacitor element is intended to represent the worst possible location under the expected low or high energy level tested. A damage to the

insulation of the container is acceptable, provided that it maintains enough insulation in order to remain in service until replacement.

5.2 Test unit

5.2.1 General

Two set-ups of the test unit are possible, as described in 5.2.2 and 5.2.3; the manufacturer shall choose the set-up and manufacture the test unit accordingly.

5.2.2 Set-up of the test unit, first method

The test unit shall be a capacitor unit comparable to the units to be manufactured, as described in Annex A, with the following features:

- The container shall be identical to that used for the units to be manufactured.
- The test unit shall contain a single active element, i.e. electrically connected to the bushings for power supply; the other elements shall be passive, i.e. not electrically connected neither to the active element nor to the bushings.
- The unit may be equipped with some means of shorting the capacitor terminals, such as metallic wires between terminals, for safe handling.
- The position of the tested element shall be located at the top location nearest to the bushing lid.
- The element shall be of the same size to that used for the units to be manufactured.

Each test shall be conducted on a separate test unit, differing for the intentional damage of the active element (as described in 5.2.4 to 5.2.5) but otherwise identical.

5.2.3 Set-up of the test unit, second method

The test unit shall be a capacitor unit comparable to the units to be manufactured, as described in Annex A, with the following features:

- The container shall be identical to that used for the units to be manufactured.
- The test unit shall have full-size active elements, with only one pre-damaged active element identical to those included in the capacitor unit supplied.
- The unit may be equipped with some means of shorting the capacitor terminals, such as metallic wires between terminals, for safe handling.
- The position of the tested element shall be located at the top location nearest to the bushing lid.
- The capacitor units shall be constructed with appropriate resistor values capable to withstand high voltage (see 5.3).

5.2.4 Active element for the low energy test

The insulating films between the two active electrodes of the element for the low energy test shall be mechanically damaged before insertion in the test unit, in order facilitate the element failure during the low energy test.

The mechanical damage shall be located at 5 ± 1 cm from the margin of the element and roughly on the fringe of the element's length as shown in Figure 1. The damage shall be located between five and ten plies from the outermost ply of the element. Two dielectric layers between consecutive metallic foils shall be separately punctured; the punctures should be sufficiently apart in order to avoid shorting the element just at the beginning of the test.

NOTE It is suggested to puncture the layers using a heated nail of about 2 mm in diameter.

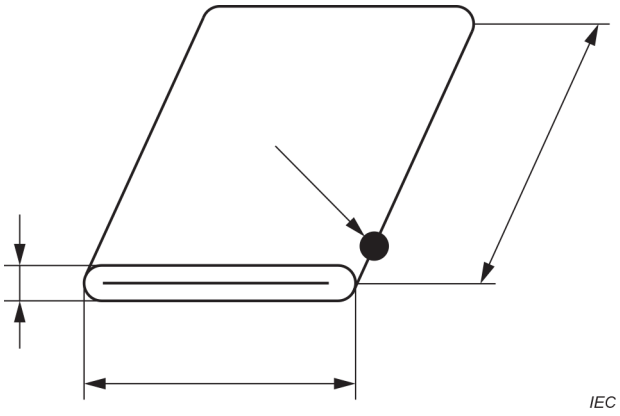

Figure 1 – Puncture location on the active element

5.2.5 Active element for the high energy test

One of the insulating films between the two active electrodes of the active element shall be mechanically damaged during manufacturing in a manner to facilitate the element failure at the time of the tests.

The mechanical damage shall be located at 5 ± 1 cm from the margin of the element and roughly on the fringe of the element's length as shown in Figure 1. The damage shall be located between five and ten plies from the outermost ply of the element. Only one dielectric layer between consecutive metallic foils shall be punctured.

NOTE It is suggested to puncture the layer using a heated nail of about 2 mm in diameter.

5.3 Conditioning of the unit

5.3.1 General

Two methods to prepare the test circuit are possible, as described in 5.3.2 and 5.3.3; the manufacturer shall choose the method and prepare the test circuit accordingly.

5.3.2 Circuit for achieving a failed test unit, first method

The electrical failure of each test unit shall be produced by the discharge of a pre-charged loading capacitor unit in parallel to the test unit. The suggested electric circuit is shown in Figure 2.