BRITISH STANDARD

BS 7631:1993
IEC 593:1977
(Incorporating Amendment 1:1980 and Amendment 2:1986)

Internal fuses and internal overpressure disconnectors for shunt capacitors

UDC 621.319.4.022[621.316.545: :531.787 + 621.316.923](– 191).001.11.001.2.001.4

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Power Electrical Engineering Standards Policy Committee (PEL/-) to Technical Committee PEL/46, upon which the following bodies were represented:

Association of Consulting Engineers
British (AC) Capacitor Manufacturers' Association (BEAMA Ltd.)
ERA Technology Ltd.
Electricity Association
Rotating Electrical Machines Association (BEAMA Ltd.)

This British Standard, having been prepared under the direction of the Power Electrical Engineering Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 March 1993

The following BSI references relate to the work on this standard:
Committee reference PEL/46
Special announcement in *BSI News*, December 1992

ISBN 0 580 21947 X

Amendments issued since publication

Amd. No.	Date	Comments

Contents

National foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee. It is identical with IEC 593:1977 *Internal fuses and internal overpressure disconnectors for shunt capacitors*, incorporating Amendment No. 1:1980 and Amendment No. 2:1986, published by the International Electrotechnical Commission (IEC).

Cross-references

The Technical Committee has reviewed the provisions of IEC 70 and IEC 70A, to which normative reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

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Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

1.1 This standard applies to internal fuses used to protect shunt capacitors in accordance with IEC Publication 70, Power Capacitors:

1.2 This standard also applies to internal overpressure disconnectors used to protect self-healing metallized dielectric capacitors in accordance with IEC Publication 70A, First supplement: Self-healing Metallized Power Capacitors.

1.3 This standard does not apply to fuses and disconnectors for which the service conditions, in general, are incompatible with the requirements of the standard, unless otherwise agreed between manufacturer and purchaser.

1.4 Fuses and disconnectors conforming to this standard are designed to isolate faulted capacitor elements or capacitor unit, to allow operation of the remaining parts of that capacitor unit and the bank in which the capacitor unit is connected. Such fuses and disconnectors are not a substitute for a switching device such as a circuit-breaker, or the external protection of the capacitor bank, or part thereof.

2 Object

The object of this standard is:

— to formulate uniform requirements regarding performance and testing;

— to provide a guide for co-ordination of fuse and disconnector protection.

3 Definitions

3.1 Definitions of capacitor parts and accessories are in accordance with IEC Publications 70 and 70A.

NOTE The word "element" in this standard is used in accordance with the definitions contained in IEC capacitor publications, and not in accordance with IEC fuse publications.

3.2
internal fuse

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

3.3
internal overpressure disconnector

a disconnecting device inside a capacitor, designed to interrupt the current path in cases of excessive rising pressure

NOTE 1 This overpressure disconnector is not a current-limiting fuse.

NOTE 2 This type of disconnector can also be placed outside the capacitor unit, but is still considered an integral part of the capacitor unit, and shall fulfil the same requirements and pass the same tests as the internal overpressure disconnector.

NOTE 3 This device is normally used in capacitors of the self-healing type.

3.4
bank protection

a general term for all protective equipment for a capacitor bank, or part thereof

3.5
unbalance protection

a device sensitive to capacitance difference between branches of the bank normally in balance with each other. The capacitance difference may be due to a blown fuse(s), or operation of a disconnector or insulation failure within the bank

NOTE Other protective devices, such as overcurrent and earth fault protection, are self-explanatory, since they are commonly used for other applications.

Section 2. Performance Requirements

4 General

4.1 The fuse is connected in series to the element(s) which the fuse is intended to isolate if the element(s) becomes faulty. The range of currents and voltages for the fuse is therefore dependent on the capacitor design, and in some cases also on the bank in which the fuse is connected.

The operation of an internal fuse is in general determined by one or both of the two following factors:

— the discharge energy from elements or units connected in parallel with the faulty element or unit;

— the power-frequency fault current.

4.2 The disconnector is intended to interrupt the current to all elements of the capacitor. The proper operation of the disconnector is dependent on the leak tightness of the container during the life of the capacitor.

5 Disconnecting requirements

5.1 The fuse shall enable the faulty element to be disconnected when electrical breakdown of elements occurs in a voltage range, in which u_1 is the lowest, and u_2 is the highest (instantaneous) value of the voltage between the terminals of the unit at the instant of fault.

The recommended values for u_1 and u_2 are given in Table I.

Table I

Rated bank voltage	u_1 (lower limit)	u_2 (upper limit)
Up to 660 V	$0.9\sqrt{2}\, U_N$	$1.5\sqrt{2}\, U_N$
Above 660 V	$0.9\sqrt{2}\, U_N$	$2.0\sqrt{2}\, U_N$

NOTE 1 The u_1 and u_2 values above are based on the voltage that may normally occur across the capacitor unit terminals at the instant of electrical breakdown of the element.

The u_2 values are of a transient nature, and allowance has been made for increased damping at low voltage.

The purchaser shall specify if the μ_1 and μ_2 values differ from those given in Table I. If so the values in Table III and Table IV shall be changed accordingly.

NOTE 2 The requirements are valid for a bank switched by a restrike-free circuit-breaker. If the breakers are not restrike-free, other requirements shall be agreed between manufacturer and purchaser.

5.2 The disconnector shall enable the faulty capacitor unit to be disconnected for voltages up to and including u_3.

The recommended r.m.s. value is $u_3 = 1.2\ U_N$.

NOTE The purchaser shall specify if this voltage will be exceeded.

6 Withstand requirements

6.1 After operation, the fuse assembly and the disconnector must withstand full element voltage and full voltage between the terminals of the disconnected capacitor respectively, plus any unbalance voltage due to fuse or disconnector action, and any short-time transient overvoltages normally experienced during the life of the capacitor.

6.2 Throughout the life of the capacitor, the disconnector shall be capable of carrying continuously a current equal to or greater than 1.1 times the maximum permissible unit current and the fuses capable of carrying continuously a current equal to or greater than the maximum permissible unit current divided by the number of parallel fused paths.

NOTE The requirements are valid if the capacitors are switched by a restrike-free circuit-breaker.

If the breakers are not restrike-free, other requirements are to be agreed between manufacturer and purchaser.

6.3 The fuse and the disconnector shall be capable of withstanding the inrush-currents due to the switching operations expected during the life of the capacitor.

6.4 The fuse connected to the undamaged element(s) must be able to carry the discharge currents due to the breakdown of element(s).

6.5 The fuses and disconnectors must be able to carry the currents due to short-circuit faults external to the unit(s) on the bank occurring within the voltage range in accordance with Table I.

Section 3. Tests

7 Routine tests

No routine tests are required.

8 Type tests

8.1 The type tests comprise:

— Discharge test (Clause **9**).

— Disconnecting test on fuses (Clause **10**).

— Disconnecting test on disconnector (Clause **11**).

In addition, the fuses and disconnectors shall be able to withstand all type tests of the capacitor units in accordance with IEC Publications 70 and 70A.

8.2 Type tests of fuses are performed either on one complete capacitor unit or, at the choice of the manufacturer, on two units, one unit being tested at the lower voltage limit, in accordance with Sub-clause **10.1**, and one unit at the upper voltage limit.

The unit(s) shall have passed all routine tests stated in IEC Publication 70.

NOTE Due to testing, measuring and safety circumstances, it may be necessary to make some modifications to the unit(s) under test; for example, those indicated in Appendix B. See also the different test methods given in Appendix B.

8.3 Type tests of disconnectors are performed on a capacitor unit that shall have passed all routine tests stated in IEC Publications 70 and 70A.

8.4 Type tests are considered valid if they are performed on capacitors of a design identical with that of the capacitor offered, or on a capacitor of a design that does not differ from it in any way that might affect the properties to be checked by the type tests.

9 Discharge test

9.1 The fuses and disconnectors shall be subjected to five discharges within 10 min from a d.c. test voltage through a gap situated as closely as possible to the capacitor, without any additional impedance in the circuit.

The test voltage shall be taken from Table II

Table II

Rated bank voltage	Test voltage (times unit voltage)
Up to 660 V	$2.0\ U_N$
Above 660 V	$2.5\ U_N$

9.2 To prove that the fuses or disconnector have not operated, a capacitance measurement shall be made before and after the test. A measuring method shall be used that is sufficiently sensitive to detect the capacitance change caused by one blown fuse.

10 Disconnecting test on fuses

10.1 Test procedure

The disconnecting test on fuses is performed first at the lower voltage limit, in accordance with Table III, and then, as soon as possible after the blowing of one fuse, at the upper voltage limit, until the blowing of another fuse.

Certain test methods are indicated in Appendix B.

Table III

Rated bank voltage	A.C. test voltage (times unit voltage)	
	Lower limit	Upper limit
Up to 660 V	0.9 U_N	1.6 U_N
Above 660 V	0.9 U_N	2.2 U_N

NOTE If the test is carried out with d.c., the test voltage shall be $\sqrt{2}$ times the corresponding a.c. test voltage.

10.2 Capacitance measurement

After the test, capacitance shall be measured, to prove that the fuse(s) has (have) blown.

A measuring method shall be used that is sufficiently sensitive to detect the capacitance change caused by one blown fuse.

10.3 Inspection of the unit

Before opening, no significant deformation of the container shall be apparent.

After opening the container, a check should be made to ensure that:

a) No significant deformation of sound fuses is apparent.

b) No more than one additional fuse (or one-tenth of fused elements directly in parallel) has been damaged (Appendix B, Note 1). If method b) in Appendix B is used, the note must be observed.

NOTE 1 A small amount of blackening of the impregnant will not affect the quality of the capacitor.

NOTE 2 Dangerous trapped charges may be present on elements disconnected either by operated fuses or by damage to their connections. All elements should be discharged with great care.

10.4 Voltage test after opening the container

A voltage test shall be carried out by applying for 10 s the voltage given by Table IV across the broken down element and the gap in its blown fuse. During the test, the gap shall be in the impregnant. No breakdown over the fuse gap is allowed.

Table IV

Rated bank voltage	D.C. test voltage (times element voltage)
Up to 660 V	2.6 U_{Ne}
Above 660 V	3.5 U_{Ne}

NOTE For units with all elements in parallel and for all units if test procedure b) or c) or d) or e) indicated in Appendix B is used, this test can be replaced by an a.c. test before the opening of the unit. The test voltage between the terminals is calculated using the capacitance ratio such that the voltage across the breakdown element and the gap in its blown fuse is the Table IV value divided by $\sqrt{2}$.

11 Disconnecting test on disconnector

11.1 Test procedure

The capacitor is preheated in a chamber before applying the test voltage until all parts reach a temperature of 60 °C.

An a.c. test voltage of 1.6 U_N shall be applied until the disconnector interrupts the current through the capacitor.

If the disconnector does not operate within 8 h, the test voltage is raised to 1.75 U_N.

If, after a further 8 h, the disconnector still has not operated, the test voltage should finally be raised to 2 U_N, until the current is interrupted.

If no interruption is achieved, the temperature may be further raised at the option of the manufacturer.

NOTE Precautions shall be taken when performing this test against the possible explosion of a capacitor unit.

11.2 Capacitance measurement

After the test, capacitance shall be measured to prove that the disconnector has operated.

11.3 Inspection of the unit

Only slight traces of impregnant on the outside of the capacitor are allowed.

11.4 Voltage tests

A voltage test between terminals shall be carried out by applying, for 10 s, an a.c. voltage equal to 2.15 U_N, or a d.c. voltage equal to 4.3 U_N.

In addition, a voltage test between terminals and container shall be made by applying, for 10 s, the test voltage given by IEC Publication 70.

The test voltages shall be applied after the capacitor has cooled to room temperature.

No internal breakdown is allowed.

NOTE The current shall be recorded during the test.

Appendix A Guide for co-ordination of fuse and disconnector protection

General

The fuse is connected in series with the element that the fuse is designed to isolate if the element becomes faulty. After the breakdown of an element, the fuse connected to it will blow, and isolate it from the remaining part of the capacitor, which allows the unit to continue in service. The blowing of one or more fuses will cause voltage changes within the bank.

The voltage across sound unit(s) must not exceed the value given in the relevant standard.

Depending on the internal connection of the units, the blowing of one or more fuses may also cause a change of voltage within the unit.

The remaining elements in a series group will have an increased working voltage, and the manufacturer shall, on request, give details of the voltage rise caused by blown fuses.

A typical arrangement of internal overpressure disconnectors in a three-phase unit can be seen in Figure 1, page 4.

In Figure 2, page 5, the operational principle of the internal overpressure disconnector can be seen.

Because of the self-healing properties of the capacitor, breakdowns are not dangerous and do not increase the current significantly. But, in the event of rising pressure (e.g., caused by thermal instability, which may occur at the end of the life of the capacitor, or, in some cases, by an excessive number of self-healing breakdowns, caused by extreme overloads) the self-healing power capacitor should be protected by an internal overpressure disconnector.

Protection sequence

The protection of a capacitor bank must operate selectively.

The first step is the fusing of the element(s) or the operation of the disconnector.

The second step is the relay protection of the bank (e.g. overcurrent or unbalance protection).

The third step is network or plant protection.

NOTE 1 Depending on the output of the bank, the design of the relay protection etc., all the three steps are not necessarily used in all capacitor banks.

NOTE 2 In large banks, an alarm stage may also be used.

NOTE 3 Unless the fuse always blows as a result of discharge energy within the voltage range in Sub-clause **5.1**, the manufacturer shall provide the current/time characteristic and tolerance of the fuse.

Typical arrangement of internal overpressure disconnectors

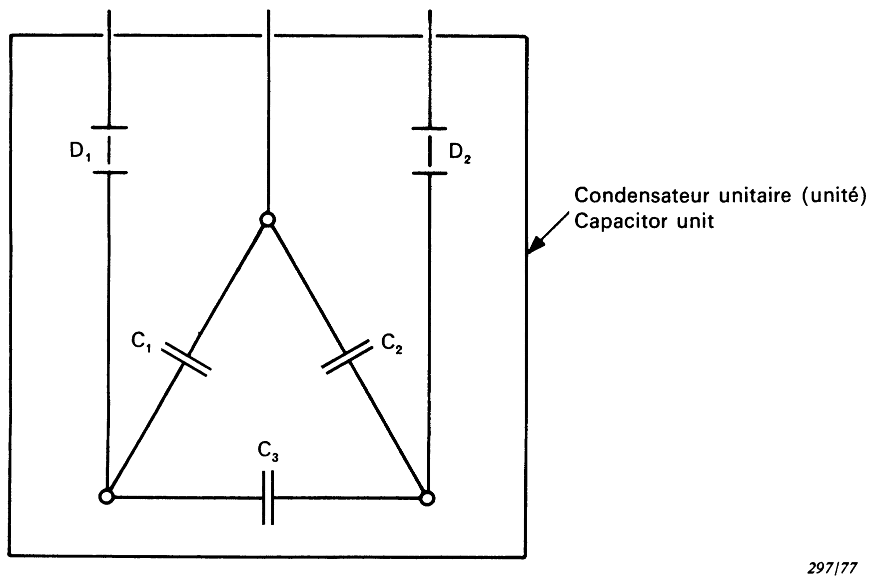

Figure 1 — Lay-out of a three-phase delta-connected capacitor unit, with two overpressure disconnectors (D_1 and D_2)

Operational principle of internal overpressure disconnectors

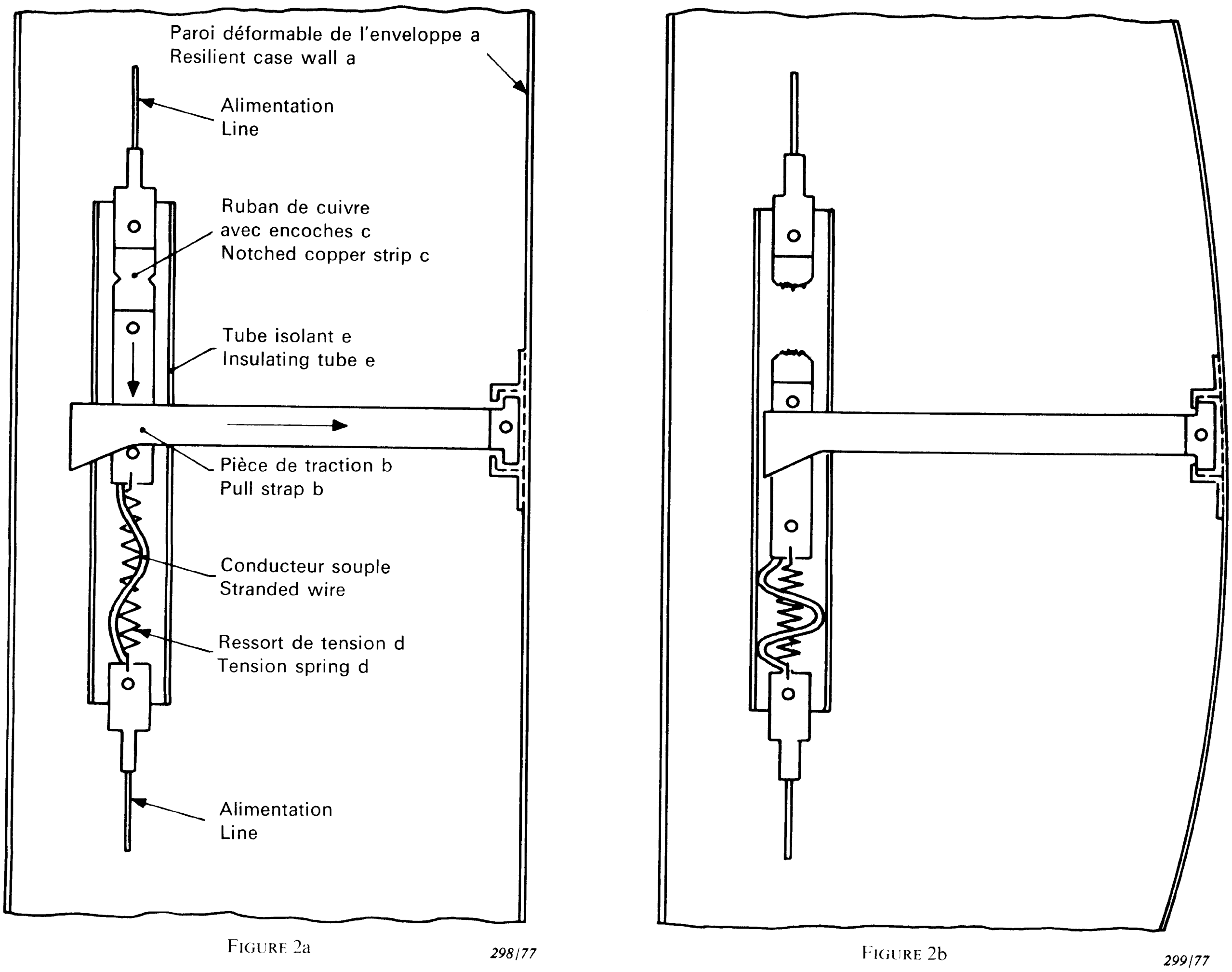

Figure 2 — Principle of design for an overpressure disconnector for self-healing, medium-voltage power capacitors

In the event of rising pressure, a resilient wall a of the container bulges out. By movement of the pull strap b, the notched copper strip c is torn into two sections. By the action of the tension spring d, the current is interrupted and the arc is extinguished very quickly, because the disconnector is installed in an oil-filled insulating tube e.

Figure 2a and Figure 2b show the overpressure disconnector before and after operation.

Appendix B Test procedures for the disconnecting test on internal fuses

General

One of the test procedures a), b), c), d), e) or an alternative method, shall be used.

If no agreement has been reached, the choice is left to the manufacturer; see also the note to Sub-clause **8.2**.

NOTE 1 At the upper voltage limit, one additional fuse (or one-tenth of the fused elements directly in parallel) connected to a sound element(s) is allowed to be damaged.

NOTE 2 The test voltage shall be maintained some seconds after a breakdown, to ensure that the fuse has disconnected correctly, unaided by disconnection of the power supply.

NOTE 3 In special cases, it may be necessary to extend the tests until two or more breakdowns of capacitor elements have occurred. The number of breakdowns at each voltage limit shall in such cases be subject to agreement between manufacturer and purchaser. If the number of breakdowns is exceeded, the voltages stated in Sub-clause **10.4** may have to be increased.

NOTE 4 To verify the current-limiting behaviour of the fuses when tested at the upper voltage limit, the voltage drop, excluding transient, across the blown fuse must not exceed 30 %.

NOTE 5 If the fuse does not fulfil the requirements of Note 4, precautions must be taken to make certain that the parallel stored energy, and the power-frequency fault current available from the system, are representative of service conditions. A test shall then be made to demonstrate satisfactory operation of the fuse.

NOTE 6 Precautions shall be taken when performing this test against the possible explosion of a capacitor unit, and the explosive projection of the nail.

a) *Capacitor preheating*

The capacitor unit is preheated in a chamber before applying the a.c. test voltage at the lower limit. Preheating temperature (100 °C to 150 °C) is chosen by the manufacturer to achieve a practical short time (some minutes to some hours) to the first breakdown.

A lower preheating temperature should be used when applying the test voltage at the higher voltage limit, to avoid breakdowns before reaching the test voltage.

Capacitor current is to be recorded during the test.

NOTE To prevent excessive internal liquid pressure due to high temperature, the unit may be equipped with a relief tube including a valve which must be closed at the instant of applying the test voltage.

b) *Mechanical puncture of the element*

Mechanical puncture of the element is made by a nail, which is forced into the element through a pre-drilled hole in the container. The test voltage may be d.c. or a.c., the choice being left to the manufacturer.

If a.c. voltage is used, capacitor current is to be recorded during the test and timing of puncture is to be made, to ascertain that the breakdown is triggered to take place at the instant of the peak of the a.c. test voltage, or very near to it.

NOTE 1 Puncture of only one element cannot be guaranteed.

NOTE 2 In order to limit the possibility of a flashover to the container along the nail, or through the hole caused by the nail, the punctures may be performed in the elements connected, permanently or during the test, to the container.

NOTE 3 D.C. voltage is especially suitable for capacitors having all elements in parallel.

c) *Electrical breakdown of the element (first method)*

Some elements in the test unit are each provided with, for example, a tab, inserted between the dielectric layers. Each tab is connected to a separate terminal.

The test voltage may be a.c. or d.c. the choice being left to the manufacturer.

To obtain breakdown of an element thus equipped, a surge voltage of sufficient amplitude is applied between tab and one of the foils of the modified element.

In the case of a.c. voltage, the surge must be triggered at the instant of the peak or very near to it.

Capacitor current is to be recorded during the test.

d) *Electrical breakdown of the element (second method)*

Certain elements in the test unit are each provided with a short fusible wire connected to two extra tabs and inserted between the dielectric layers. Each tab is connected to a separate insulated terminal.

The test voltage may be d.c. or a.c., the choice being left to the manufacturer.

To obtain breakdown of an element equipped with this fusible wire, a separate capacitor charged to a sufficient voltage is discharged into the wire in order to explode it.

In the case of a.c. voltage, the discharge of the charged capacitor causing the wire explosion shall be triggered close to the instant of the peak voltage.

Capacitor current shall be recorded during the test.

e) *Electrical breakdown of the element (third method)*

A small part of an element (or of several elements) in a unit is removed at the time of manufacture and replaced with a weaker dielectric.

For example: 10 cm^2 to 20 cm^2 of a film—paper—film dielectric is cut out and replaced with two thin papers.

List of references

See national foreword.

BSI — British Standards Institution

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