

High-voltage fuses —

Part 1: Current-limiting fuses

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- Institution of Electrical Engineers
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National foreword

This British Standard has been prepared by Subcommittee PEL/32/1 and is the English language version of EN 60282-1:1996 *High-voltage fuses* — *Part 1: Current-limiting fuses*, including amendments A1:1996 and A2:1997 and corrigendum December 1997, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 60282-1:1994 including amendments 1:1996 and 2:1997, published by the International Electrotechnical Commission (IEC).

This British Standard supersedes BS EN 60282-1:1993 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

Cross-references

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Summary of pages

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English version

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(includes amendments A1:1996 and A2:1997)

(IEC 60282-1:1994 + A1:1996 + A2:1997)

Fusibles à haute tension

Partie 1: Fusibles limiteurs de courant

(inclut les amendements A1:1996 et A2:1997)

(CEI 60282-1:1994 + A1:1996 + A2:1997)

Hochspannungssicherungen

Teil 1: Strombegrenzende Sicherungen

(enthält Änderungen A1:1996 und A2:1997)

(IEC 60282-1:1994 + A1:1996 + A2:1997)

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Foreword

The text of the International Standard IEC 282-1:1994, prepared by SC 32A, High-voltage fuses, of IEC TC 32, Fuses, was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 60282-1 on 1995-11-28 without any modification.

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Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given for information only. In this standard, Annex A, Annex E and Annex ZA are normative and Annex B, Annex C, Annex D and Annex F informative. Annex ZA has been added by CENELEC.

Foreword to amendment A1

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- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 1998-07-01

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Section 1. General

1 Scope

This standard applies to all types of high-voltage current-limiting fuses designed for use outdoors or indoors on alternating current systems of 50 Hz and 60 Hz and of rated voltages exceeding 1 000 V. Some fuses are provided with fuse-links equipped with an indicating device or a striker. These fuses come within the scope of this standard, but the correct operation of the striker in combination with the tripping mechanism of the switching device is outside the scope of this standard; see IEC 420.

1.1 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 282. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 282 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(151):1978, *International Electrotechnical Vocabulary (IEV) — Chapter 151: Electrical and magnetic devices*.

IEC 50(441):1984, *International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and fuses*.

IEC 56:1987, *High-voltage alternating-current circuit-breakers*.

IEC 60-1:1989, *High-voltage test techniques — Part 1: General definitions and test requirements*.

IEC 85:1984, *Thermal evaluation and classification of electrical insulation*.

IEC 265-1:1983, *High-voltage switches — Part 1: High-voltage switches for rated voltages above 1 kV and less than 52 kV*.

IEC 420:1990, *High-voltage alternating current switch-fuse combinations*.

IEC 549:1976, *High-voltage fuses for the external protection of shunt power capacitors*.

IEC 644:1979, *Specification for high-voltage fuse-links for motor circuit applications*.

IEC 787:1983, *Application guide for the selection of fuse-links of high-voltage fuses for transformer circuit applications*.

ISO 179:1993, *Plastics — Determination of Charpy impact strength*.

ISO R/442:1965, *Verification of pendulum impact testing machines for testing steels*.

2 Normal and special service conditions

2.1 Normal service conditions

Fuses complying with this standard are designed to be used under the following conditions:

- a) The maximum ambient air temperature is 40 °C and its mean measured over a period of 24 h does not exceed 35 °C.

The minimum ambient air temperature is –25 °C.

NOTE This does not apply to time/current characteristics of fuses which will be modified appreciably at the minimum temperatures.

- b) The altitude does not exceed 1 000 m (3 300 ft).

NOTE 1 The rated voltages and insulation levels specified in this standard apply to fuses intended for use at altitudes not exceeding 1 000 m (3 300 ft). When fuses incorporating external insulation are required for use at altitudes above 1 000 m (3 300 ft) one or other of the following procedures should be adopted:

- 1) The test voltages for insulating parts in air should be determined by multiplying the standard test voltages given in Table 6 and Table 7 by the appropriate correction factor given in column (2) of Table 1.
- 2) The fuses may be selected with a rated voltage which, when multiplied by the appropriate correction factor given in column (3) of Table 1 is not lower than the highest voltage of the system.

For altitudes between 1 000 m (3 300 ft) and 1 500 m (5 000 ft) and between 1 500 m (5 000 ft) and 3 000 m (10 000 ft), the correction factors can be obtained by linear interpolation between the values in Table 1.

Table 1

Maximum altitude m (ft) (1)	Correction factor for test voltages referred to sea level (2)	Correction factor for rated voltages (3)
1 000 (3 300)	1,0	1,0
1 500 (5 000)	1,05	0,95
3 000 (10 000)	1,25	0,80

Where the dielectric characteristics are identical at any altitude, no special precautions need to be taken.

NOTE 2 The rated current or the temperature-rise specified in this standard can be corrected for altitudes exceeding 1 000 m (3 300 ft) by using appropriate factors given in Table 2, columns (2) and (3) respectively. Use one correction factor from columns (2) or (3), but not both, for any one application.

For altitudes between 1 000 m (3 300 ft) and 1 500 m (5 000 ft) and between 1 500 m (5 000 ft) and 3 000 m (10 000 ft), the correction factors can be obtained by linear interpolation, between the values in Table 2.

Table 2

Maximum altitude m (ft) (1)	Correction factor for rated current (2)	Correction factor for temperature-rise (3)
1 000 (3 300)	1,0	1,0
1 500 (5 000)	0,99	0,98
3 000 (10 000)	0,96	0,92

c) The ambient air is not excessively (or abnormally) polluted by dust, smoke, corrosive or flammable gases, vapour or salt.

d) For indoor installations, the conditions of humidity are under consideration but, in the meantime, the following figures can be used as a guide:

— the average value of the relative humidity, measured during a period of 24 h, does not exceed 95 %;

— the average value of the vapour pressure, for a period of 24 h, does not exceed 22 mbar;

— the average value of the relative humidity, for a period of one month, does not exceed 90 %;

— the average value of the vapour pressure, for a period of one month, does not exceed 18 mbar.

For these conditions, condensation may occasionally occur.

NOTE 1 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2 To withstand the effects of high humidity and occasional condensation, such as breakdown of insulation or corrosion of metallic parts, indoor fuses designed for such conditions and tested accordingly or outdoor fuses may be used.

NOTE 3 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment.

e) Vibrations due to causes external to fuses or earth tremors are negligible.

In addition, for outdoor installations:

f) Account should be taken of the presence of condensation or rain and rapid temperature changes.

g) The wind pressure does not exceed 700 Pa (corresponding to 34 m/s wind speed).

h) The temperature due to sunlight does not exceed an equivalent black-body temperature of 80 °C.

2.2 Special service conditions

By agreement between manufacturer and user, high-voltage fuses may be used under conditions different from the normal service conditions given in 2.1. For any special service condition, the manufacturer shall be consulted.

Section 2. Definitions

The reference numbers in brackets are those of IEC 50(151)¹⁾ and 50(441)²⁾.

For the purposes of this International Standard, the following definitions apply.

3 Electrical characteristics

3.1

rated value

a quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment [151-04-03]

NOTE Example of rated values usually stated for fuses: voltage, current, breaking current.

3.2

rating

the set of rated values and operating conditions [151-04-04]

3.3

prospective current (of a circuit and with respect to a fuse)

the current that would flow in the circuit if the fuse were replaced by a conductor of negligible impedance [441-17-01]

NOTE For the method to evaluate and to express the prospective current, see 13.2.1 and 13.2.2.

3.4

prospective peak current

the peak value of a prospective current during the transient period following initiation [441-17-02]

NOTE The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, for example polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

3.5

prospective breaking current

the prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process [441-17-06]

NOTE For the fuses, this instant is usually defined as the moment of the initiation of the arc during the breaking process. Conventions relating to the instant of the initiation of the arc are given in 13.2.3.

¹⁾ IEC 50(151): *International Electrotechnical Vocabulary (IEV) — Chapter 151: Electrical and magnetic devices.*

²⁾ IEC 50(441): *International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear and controlgear.*

3.6 cut-off current; let-through current

the maximum instantaneous value of current attained during the breaking operation of a fuse [441-17-12]

NOTE This concept is of particular importance when the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

3.7 breaking capacity

a value of prospective current that a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

3.8 pre-arcing time; melting time

the interval of time between the beginning of a current large enough to cause a break in the fuse-element(s) and the instant when an arc is initiated [441-18-21]

3.9 arcing time

the interval of time between the instant of the initiation of the arc in a fuse and the instant of final arc extinction in that fuse [441-17-37]

3.10 operating time; total clearing time

the sum of the pre-arcing time and the arcing time [441-18-22]

3.11 I^2t ; joule integral

the integral of the square of the current over a given time interval:

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

NOTE 1 The pre-arcing I^2t is the I^2t integral extended over the pre-arcing time of the fuse.

NOTE 2 The operating I^2t is the I^2t integral extended over the operating time of the fuse.

NOTE 3 The energy in joules liberated in one ohm (1 Ω) of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in $A^2 \cdot s$.

3.12 virtual time

the value of Joule integral divided by the square of the value of the prospective current

NOTE The values of virtual times usually stated for a fuse-link are the values of pre-arcing time and of operating time.

3.13 time-current characteristic

a curve giving the time, for example pre-arcing time or operating time, as a function of the prospective current under stated conditions of operation [441-17-13]

3.14 cut-off (current) characteristic; let-through (current) characteristic

a curve giving the cut-off current as a function of the prospective current, under stated conditions of operation [441-17-14]

NOTE In the case of a.c., the values of the cut-off current are the maximum values which can be reached whatever the degree of asymmetry. In the case of d.c., the values of the cut-off current are the maximum values reached related to the time-constant as specified.

3.15 recovery voltage

the voltage which appears across the terminals of a fuse after the breaking of the current [441-17-25]

NOTE This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency or the steady-state recovery voltage alone exists.

3.16 transient recovery voltage (abbreviation TRV)

the recovery voltage during the time in which it has a significant transient character [441-17-26]

NOTE 1 The transient recovery voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and the fuse. It includes the voltage shift of the neutral point of a polyphase circuit.

NOTE 2 The transient recovery voltage in three-phase circuits is, unless otherwise stated, that across the first fuse to clear, because this voltage is generally higher than that which appears across each of the other two fuses.

3.17 power frequency recovery voltage

the recovery voltage after the transient voltage phenomena have subsided [441-17-27]

3.18 D.C. steady-state recovery voltage

the recovery voltage in a d.c. circuit after the transient voltage phenomena have subsided, expressed by the mean value where ripple is present [441-17-28]

3.19 prospective transient recovery voltage (of a circuit)

the transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device [441-17-29]

NOTE The definition assumes that the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the “natural” zero. For circuits where the current can follow several different paths, for example a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

3.20 short-circuit breaking power factor

no definition at present

3.21 switching voltage

the maximum instantaneous value of voltage which appears across the terminals of a fuse during its operation [441-18-31]

NOTE The switching voltage may be the arc voltage or may occur during the time of transient recovery voltage.

3.22 minimum breaking current

a minimum value of prospective current that a fuse-link is capable of breaking at a stated voltage under prescribed conditions of use and behaviour [441-18-29]

3.23 power dissipation (of a fuse-link)

the power released in a fuse-link carrying a stated value of current under prescribed conditions of use and behaviour

NOTE The prescribed conditions of use and behaviour usually include a constant r.m.s. value of current until steady temperature conditions are reached.

3.24 power acceptance of a fuse-base (fuse-holder)

the maximum value of power released in a fuse-link which a fuse-base (fuse-holder) is designed to tolerate under specified conditions

4 Fuses and their component parts

4.1 fuse

a device that by the fusing of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device [441-18-01]

4.2 terminal

a conducting part of a fuse provided for an electric connection to external circuits

NOTE Terminals may be distinguished according to the kind of circuits for which they are intended (e.g. main terminal, earth terminal, etc.), but also according to their design (e.g. screw terminal, plug terminal, etc.).

4.3 fuse-base; fuse-mount

the fixed part of a fuse provided with contacts and terminals [441-18-02]

NOTE The fuse-base comprises all the parts necessary for insulation. (See Figure 1.)

4.4 fuse-base contact

the contact piece of a fuse-base designed to engage with a fuse-carrier contact or with a fuse-link contact (See Figure 1.) [441-18-03]

4.5 fuse-carrier

the movable part of a fuse designed to carry a fuse-link (See Figure 1.) [441-18-13]

NOTE The fuse-carrier does not include the fuse-link.

4.6 fuse-carrier contact

the contact piece of a fuse-carrier designed to engage with a fuse-base contact (See Figure 1.) [441-18-05]

4.7 fuse-holder

the combination of a fuse-base with its fuse-carrier [441-18-14]

4.8 fuse-link

the part of a fuse [including the fuse-element(s)] intended to be replaced after the fuse has operated (See Figure 1.) [441-18-09]

4.9 fuse-link contact

the contact piece of a fuse-link designed to engage with a fuse-base contact or with a fuse-carrier contact (See Figure 1.) [441-18-04]

4.10 fuse-element

a part of the fuse-link designed to melt under the action of current exceeding some definite value for a definite period of time (See Figure 1.) [441-18-08]

4.11 indicating device; indicator

a part of a fuse provided to indicate whether the fuse has operated (See Figure 1.) [441-18-17]

4.12 striker

a mechanical device forming part of a fuse-link which, when the fuse operates, releases the energy required to cause operation of other apparatus or indicators or to provide interlocking [441-18-18]

5 Additional terms

5.1

general purpose fuse

see 7.1.1

5.2

back-up fuse

see 7.1.2

5.3

current-limiting fuse-link

a fuse-link that, during and by its operation in a specified current range, limits the current to a substantially lower value than the peak value of the prospective current [441-18-10]

5.4

isolating distance (for a fuse)

the shortest distance between the fuse-base contacts or any conductive parts connected thereto, measured on a fuse with the fuse-link or fuse-carrier removed [411-18-06]

5.5

homogeneous series (of fuse-links)

a series of fuse-links, deviating from each other only in such characteristics that, for a given test, the testing of one or a reduced number of particular fuse-link(s) of that series may be taken as representative for all the fuse-links of the homogeneous series (See 13.3.1.) [441-18-34]

5.6

external insulation

the distances in atmospheric air and the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity, vermin, etc

5.7

full-range fuse

see 7.1.3

Section 3. Ratings and standard conditions of use and behaviour

6 Ratings

6.1 Rated voltage

A voltage used in the designation of the fuse-base or fuse-link, from which the test conditions are determined.

NOTE This rated voltage is equal to the highest voltage for the equipment. (See section 7.)

6.2 Rated current of the fuse-base

The current assigned to a fuse-base that a new clean fuse-base will carry continuously without exceeding specified temperature-rises, when equipped with a fuse-link of the same current-rating designed to be used in the particular fuse-base connected to the circuit with certain specified conductor sizes and length, at an ambient air temperature of not more than 40 °C.

6.3 Rated current of the fuse-link

The current assigned to the fuse-link that a new clean fuse-link will carry continuously without exceeding specified temperature-rises when mounted on a fuse-base specified by the manufacturer and connected to the circuit with certain specified conductor sizes and lengths, at an ambient air temperature of not more than 40 °C. (See section 7.)

6.4 Rated frequency

The frequency for which the fuse has been designed and to which the values of the other characteristics correspond.

6.5 Rated breaking current

6.5.1 Rated maximum breaking current

The value of breaking capacity specified for a fuse.

6.5.2 Rated minimum breaking current

The value of minimum breaking current specified for a back-up fuse.

6.6 Rated insulation level (of a fuse-base)

The voltage values (both power-frequency and impulse) which characterize the insulation of the fuse-base with regard to its capability of withstanding the dielectric stresses (see section 7). Two levels of dielectric withstand are recognized for a fuse-base according to European practice. These are termed "List 1" and "List 2" and relate to different severities of application and corresponding different values of test voltage for the dielectric tests.

See 18.6, Table 6 (series I) and 22.6.

6.7 Rated transient recovery voltage (rated TRV)

The rated transient recovery voltage related to the rated maximum breaking current (in accordance with 6.5) is the reference voltage which constitutes the upper limit of the prospective transient recovery voltage of circuits which the fuse shall be capable of breaking in the event of a short circuit.

6.7.1 Representation of TRV

The waveform of transient recovery voltage varies according to the arrangement of the actual circuits.

For fuses covered by the scope of this standard, the transient recovery voltage approximates to a damped single-frequency oscillation. This waveform is adequately described by an envelope consisting of two line segments defined by means of two parameters (reference line)³⁾.

The influence of local capacitance on the source side of the fuse produces a slower rate-of-rise of the voltage during the first few microseconds of the TRV. This is taken into account by introducing a time delay.

This representation applies both to rated and to other specified transient recovery voltages which are represented by two parameter reference lines together with delay lines.

6.7.2 Representation of rated TRV

The following parameters are used for the representation of the rated TRV (see Figure 8):

u_c = TRV peak voltage in kilovolts

t_3 = time in microseconds to voltage u_c

a delay line starting on the time axis at the rated time delay t_d running parallel to the first section of the reference line and terminating at a specified voltage u' (time coordinate t').

6.7.3 Standard values of rated TRV

Standard values of rated TRV are specified in section 6. These values apply to the rated breaking current of a fuse.

7 Standard conditions of use and behaviour

7.1 Classes

Three classes of current-limiting fuses are defined according to the range in which they can be used: back-up fuses, general purpose fuses and full range fuses. See 22.4.

7.1.1 General purpose fuse

A current-limiting fuse capable of breaking, under specified conditions of use and behaviour, all currents from the rated maximum breaking current down to the current that causes melting of the fuse-element in 1 h or more.

7.1.2 Back-up fuse

A current-limiting fuse capable of breaking, under specified conditions of use and behaviour, all currents from the rated maximum breaking current down to the rated minimum breaking current.

Back-up fuses are generally associated with other apparatus such as a switch.

7.1.3 Full-range fuse

A current-limiting fuse capable of breaking, under specified conditions of use and behaviour, all currents that cause melting of the fuse-element(s) up to its rated maximum breaking current.

7.2 Breaking characteristics

7.2.1 General

When used in systems with service voltages less than the rated voltage of the fuse, the breaking current in kiloamperes is not less than the rated maximum breaking current.

Current-limiting fuses should not be used in systems of voltages less than their rated voltage without regard to the switching-voltage produced by the fuse during operation in relation to the insulation level.

No tests have been specified to prove the performance of the fuse in the range of currents below that specified in the breaking tests in section 4 with respect to its capability to withstand the current of every possible time/current combination without deterioration leading to either premature operation or failure. (See section 7.)

7.2.2 Standard conditions of use with respect to breaking capacity

Fuses shall be capable of breaking correctly any value of prospective current, irrespective of the possible d.c. component, provided that:

- the a.c. component is not lower than the rated minimum breaking current and not higher than the rated maximum breaking current.
- the power-frequency recovery voltage is not higher than that specified in Table 4 (for special conditions, see 22.5);
- the prospective transient recovery voltage is within the limits represented by the tests specified in 13.1.2;
- the frequency is between 48 Hz and 62 Hz;
- the power factor is not lower than that represented by the tests specified in Table 4;
- the prospective TRV wave, while passing through the delay line and not recrossing it, does not exceed the reference line with the parameters specified in 13.1.2.

NOTE As regards the prospective TRV characteristics, the time co-ordinate t_3 is not significant for the behaviour of fuses (except for those fuses, which cause high arc-voltage peaks immediately after arc initiation; see 13.1.2.1).

³⁾ See Annex A.

7.2.3 Standard conditions of behaviour with respect to breaking capacity

According to the conditions of use indicated in 7.2.2, the behaviour of the fuse shall be as follows:

a) A powder-filled fuse-link shall not emit flame or powder, although a minor emission of flame from a striker or indicating device is permissible, provided this does not cause breakdown or significant electrical leakage to earth.

b) After the fuse has operated, the components of the fuse, apart from those intended to be replaced after each operation, shall be in the original state. It shall be possible to remove the fuse-link in one piece after operation.

However, it is permissible for the components designed to secure the fuse-element in renewable fuses to be slightly damaged, if such damage is not likely to prevent the replacement of the melted fuse-element, to decrease the breaking capacity of the fuse, to modify its operating characteristics, or to increase its temperature-rise in normal service.

c) When fuse-links are provided with indicating devices or strikers:

- 1) indicating devices need not comply with specific requirements, but shall visually and fully operate;
- 2) strikers shall comply with the requirements specified in 18.13 and shall operate fully.

d) Operation shall not generate switching-voltages higher than the values specified in 18.8.

e) The values of cut-off current corresponding to each value of prospective breaking current shall not exceed the values corresponding to the cut-off characteristics given by the manufacturer.

f) After operation, the fuse shall be capable of withstanding the power-frequency recovery voltage across its terminals.

7.3 Time-current characteristics

The time-current characteristics of fuse-links are based on applying current to a new and unloaded fuse-link in a fuse-base specified by the manufacturer and connected to the test-circuit with conductor sizes and lengths as specified in 12.1.2.

Unless otherwise specified, the time-current characteristics shall be deemed to apply at an ambient air temperature of 20 °C.

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7.4 Environmental behaviour

Fuses complying with this standard are inert devices during normal service. It is also a requirement of 7.2.3 that no significant external emission takes place. Therefore they are regarded as environmentally safe devices in service and operation. Ⓐ

Section 4. Type tests

8 Conditions for making the tests

Type tests are made to check whether a type or particular design of fuse corresponds to the characteristics specified and functions satisfactorily under normal behaviour conditions or under special specified conditions. Type tests are made on samples to check the specified characteristics of all fuses of the same type.

These tests shall be repeated only if the construction is changed in a way which might modify the performance.

Tests made on fuse-links fitted with strikers are valid for fuse-links without strikers.

For convenience of testing, and with the previous consent of the manufacturer, the values prescribed for the tests, particularly the tolerances, can be so changed as to make the test conditions more severe. Where a tolerance is not specified, type tests shall be carried out at values not less severe than the specified values: the upper limits are subject to the consent of the manufacturer.

Tests specified in this standard are, in principle, type tests, and methods of sampling for acceptance tests are not given.

If the user wishes to make acceptance tests, these tests shall be selected from the type tests after agreement between manufacturer and user.

Where tests are made on a fuse whose report of type tests has already been accepted, the responsibility of the manufacturer to the user is limited to the least onerous of the specified values and not to the values obtained during the type tests. For example, although breaking tests may have been made at 103 % of the specified power-frequency recovery voltage, nevertheless the manufacturer is not liable for any performance figures exceeding 100 % of the specified power-frequency recovery voltage.

9 List of type tests

The type tests to be conducted upon completion of a design or following a change that affects the performance are the following:

— dielectric tests;

- temperature-rise tests and power-dissipation measurement;
- breaking tests;
- tests for time-current characteristics;
- oil-tightness tests (only for fuses intended to be used in oil);
- tests of strikers.

Before the tests are made, with the exception of dielectric and oil-tightness tests, the resistance of each fuse-link shall be measured with a current not exceeding 10 % of the rated current. The value of resistance shall be recorded together with the ambient air temperature at which the measurement was taken.

The results of all type tests shall be recorded in type-test reports containing the data necessary to prove compliance with this standard.

Fuses within the scope of this standard are not sensitive to electromagnetic disturbances and therefore no immunity tests are necessary. Any electromagnetic disturbance which may be generated by a fuse is limited to the instant of its operation. Provided the switching voltage values during type-tests do not exceed those given in Table 9 of this standard, no other tests for electromagnetic compatibility are required.

10 Common test practices for all type tests

The following shall be common test practices, unless otherwise specified.

10.1 Condition of device to be tested

The device shall be new, clean and in good condition.

10.2 Mounting of fuses

The fuse to be tested shall be mounted on a rigid earthed metal structure in the normal service position for which it is designed.

Unless otherwise specified, the connections shall be so positioned that the normal clearances are not reduced.

11 Dielectric tests

11.1 Test practices

Dielectric test practices shall be as specified in clause 10 and as follows.

NOTE Fuse-links cannot be tested as separate devices either in the intact or in the operated state.

11.1.1 Mounting

For multi-pole arrangements of fuses, and when the distance between poles is not fixed by their construction, it is necessary, for test purposes, to provide the minimum distance between poles as specified by the manufacturer.

11.1.2 Electrical connections

Electrical connections shall be made by means of bare conductors connected to each terminal. These conductors shall project from the terminals of the fuse in a straight line substantially parallel to the fuse-link for an unsupported distance of at least the isolating distance of the fuse.

11.2 Application of test voltage for impulse and power-frequency tests

The test voltage specified in Table 6 and Table 7 for the fuse under test shall be applied successively with one terminal of the output of the impulse generator and one point of the power-frequency source connected to earth:

- a) Between terminals and all earthable metal parts:
 - 1) with the fuse including the fuse-link and its fuse-carrier completely assembled ready for service;
 - 2) with the fuse-link removed.

NOTE For multi-pole arrangements of fuses:

- 1) Between all live parts of all poles connected together and the earthable metal parts.
- 2) Between the terminals of each pole and the earthable metal parts with all the live parts of the other poles connected to the earthable metal parts.

- b) Between terminals: these tests are made on fuse-bases only.

The earthable metal parts shall be connected to earth if isolating properties are not assigned to the fuses. If isolating properties are assigned to the fuse, earthable metal parts shall either be insulated from the earth or connected to the mid-point of the source.

NOTE For multi-pole arrangements of fuses, the terminals of one side should be connected together and the terminals of the opposite side should be connected together.

11.3 Atmospheric conditions during test

The test shall be made at atmospheric conditions as near as possible to the standard conditions specified in IEC 60-1, subclause 10.2.

The correction factors for air density and for air humidity as given in IEC 60-1, subclauses 10.3 and 10.4, may be used for fuses pending further information.

11.4 Test voltages

The test voltages to be used for the tests prescribed in clause 11 shall be in accordance with those given in section 6.

11.5 Lightning impulse voltage dry tests

Fuses shall be subjected to lightning impulse voltage dry tests with 1,2/50 impulses in accordance with IEC 60-1, section 6.

Fifteen consecutive impulses at the rated lightning impulse withstand voltages specified in Table 6 and Table 7 shall be applied as follows:

- at the rated withstand voltage to earth and between poles for all the test conditions a) of 11.2;
- at the rated withstand voltage to earth and between poles for the test condition b) of 11.2 if isolating properties are not assigned to the fuse-base;
- at the rated withstand voltage across the isolating distance for the test condition b) of 11.2 if isolating properties are assigned to the fuse-base.

The fuse shall be considered to have passed the test successfully if the number of disruptive discharges to earth, between poles or between terminals on self-restoring insulation, does not exceed two for each test condition and if no disruptive discharge on non-self-restoring insulation occurs.

The fuse shall be capable of passing the specified tests with voltages of both positive and negative polarity, but where there is evidence as to which polarity will give the lower break-down voltage, it shall suffice to test with that polarity only.

11.6 Power-frequency voltage dry tests

Fuses shall be subjected to one-minute power-frequency voltage dry tests, as specified in IEC 60-1.

The test circuit (transformer with voltage-regulating device) shall have a short-circuit current of at least 0,2 A. It is permissible to check the magnitude of the current at approximately one-tenth of the specified voltage.

The values for the rated one-minute power-frequency withstand voltage tests are specified in Table 6 and Table 7. The tests shall be made at the following values:

- at the rated withstand voltage to earth and between poles for all the test conditions a) of 11.2;
- at the rated withstand voltage to earth and between poles for the test conditions b) of 11.2 if isolating properties are not assigned to the fuse-base;

- at the rated withstand voltage across the isolating distance for the test condition b) of 11.2 if isolating properties are assigned to the fuse-base.

If flashover or puncture occurs, the fuse shall be considered to have failed the test.

11.7 Power-frequency wet tests

Outdoor type fuses shall be subjected to power-frequency voltage wet tests under the same conditions as specified in 11.6 except for the duration, which is 1 min according to European practice and 10 s according to U.S.A. and Canadian practice. However, if a disruptive discharge on external self-restoring insulation occurs, this test shall be repeated with the same test conditions and the fuse shall be considered to have passed this test successfully if no further disruptive discharge occurs.

During these tests, the fuses shall be subjected to artificial rain at an angle of 45° to the vertical, the test procedure being in accordance with IEC 60-1, clause 9.

12 Temperature-rise tests and power-dissipation measurement

12.1 Test practice

Temperature-rise tests and power-dissipation measurement shall be made as specified in clause 10 on one fuse and as follows.

12.1.1 Test sample

The fuse-base shall be as specified by the manufacturer of the fuse-link being tested.

The fuse-link shall be of the highest current-rating for use in the fuse-base.

12.1.2 Arrangement of the equipment

The test shall be made in a closed room substantially free from air currents, except those generated by heat from the device being tested.

The fuse in air shall be mounted in the most unfavourable position within the instructions specified by the manufacturer and connected to the test circuit by bare copper conductors as follows: each conductor shall be approximately 1 m (3 1/4 ft) long, mounted in a plane parallel to the mounting surface of the fuse, but it may be in any direction in this plane. The sizes of the leads are given in Table 3.

Table 3

Current-rating of the fuse-link A	Size of bare copper conductors mm ²
Up to and including 25	From 20 to 30
Above 25 up to and including 63	From 40 to 60
Above 63 up to and including 200	From 120 to 160
Above 200 up to and including 400	From 250 to 350
Above 400 up to and including 630	From 500 to 600
Above 630 up to and including 1 000	From 800 to 1 000

NOTE 1 The equivalent area in MCM (one thousand circular mils) can be obtained by multiplying the above numbers in the second column by two.

NOTE 2 For fuse-links in parallel, the current rating to be considered is the total current assigned by the manufacturer.

Oil-tight fuse-links for use in switchgear shall be tested in an oil-filled enclosure designed to simulate service conditions. The volume of this enclosure shall be about 30 times the volume of the fuse-link under test. The fuse-link shall be immersed in such a manner that the oil is equally distributed around the fuse-link. Annex C gives an example of preferred testing arrangements for fuse-links up to 200 A in accordance with data sheet II of Annex D. The test conductors external to the tank shall be arranged as given in the preceding paragraph, with the sizes as given in Table 3.

Normal clearances need not be provided.

Tests shall be made with the rated current of the fuse-link and at a frequency between 48 Hz and 62 Hz. Each test shall be made over a period of time sufficient for the temperature rise to reach a constant value (for practical purposes, this condition is regarded as being obtained when the increase of temperature rise does not exceed 1 K per hour).

The temperature rise of the various parts of the fuse shall not exceed the specified values in section 6.

12.2 Measurement of temperature

All reasonable precautions shall be taken to reduce the variations and the errors due to the time lag between the temperature of the fuse and the variations in the ambient air temperature.

12.2.1 Temperature of fuse parts

The temperature of the various parts for which limits are specified shall be determined by devices such as thermocouples, thermometers or contact elements located and secured to provide good heat conduction at the hottest accessible spot. The temperature-rise shall be recorded at regular intervals throughout the test when the calculation of the thermal time constant is needed.

The surface temperature of a component immersed in a liquid dielectric shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured in the upper layer of the dielectric.

For measurement with thermometers or thermocouples, the following precautions shall be taken:

- The bulbs of the thermometers or thermocouples shall be protected against cooling from outside (dry clean wool, etc.). The protection area shall, however, be negligible compared to the cooling area of the apparatus under test.
- Good heat conductivity between the thermometer or thermocouple and the surface of the part under test shall be ensured.
- When bulb thermometers are employed in places where there is a varying magnetic field, it is recommended to use alcohol thermometers in preference to mercury thermometers, as the latter are more liable to be influenced under these conditions.

12.2.2 Ambient air temperature

The ambient air temperature is the average temperature of the air surrounding the fuse (for enclosed fuses, it is the air outside the enclosure). It shall be measured during the last quarter of the test period by means of at least three thermometers, thermocouples or other temperature detecting devices equally distributed around the fuse at about the average height of its current-carrying parts at a distance of about 1 m from the fuse. The thermometers or thermocouples shall be protected against air currents and undue influence of heat.

In order to avoid indication errors because of rapid temperature changes, the thermometers or thermocouples may be put into small oil-filled bottles with oil contents of about half a litre.

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 h. If this is not possible because of unfavourable temperature conditions of the test room, the temperature of an identical fuse under the same conditions, but without current, can be taken as a substitute for the ambient air temperature. This additional fuse shall not be subjected to an undue amount of heat.

The ambient air temperature during tests shall be between + 10 °C and + 40 °C. No correction of the temperature-rise values shall be made for ambient air temperature within this range.

12.3 Measurement of power dissipation

Fuses intended for use in enclosures may require derating (see 22.2 and Annex F). To facilitate this derating, measurement of the power dissipation shall be made.

NOTE 1 This requirement applies only to fuses intended for use in enclosures. For other fuses, see 17.1: special tests.

The measurement of power dissipation can be made during the temperature-rise test. Two values shall be measured, one at 50 % and the second at 100 %, of the rated current of the fuse-link.

The voltage shall be measured on the fuse-link contacts as close as possible to the point of contact with the immediately mating contact piece.

The measurement shall be made when the power dissipation has reached a steady-state value for the current value considered.

The power dissipation is expressed in watts.

NOTE 2 Switchgear manufacturers who incorporate fuses into their equipment may take account of the power-dissipation values to determine derating factors for different types of fuses fitted into their equipment. The power-dissipation value is not the only parameter to define derating factors.

13 Breaking tests

13.1 Test practices

Breaking test practices shall be as specified in clause 10 and as follows.

13.1.1 Description of tests to be made

Tests shall be made according to the instructions given in Table 4 and shall include three test duties, giving the most severe breaking conditions throughout the range of operating currents:

Test duty 1: Verification of operation with the rated maximum breaking current I_1 (see notes 1, 3, 4 and 5).

Test duty 2: Verification of the operation with prospective current I_2 at which current limitation occurs when a high level of energy is stored in the inductance of the circuit (see notes 1 to 4).

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Test duty 3: Verification of operation at current I_3 (see note 1):

— for back-up fuses, I_3 is the rated minimum breaking current;

— for general purpose fuses, I_3 is the current that causes melting in one hour or more;

— for full-range fuses, I_3 is equal to the rated current of the fuse-link, except where the fuse-link is designed for use in a surrounding temperature above 40 °C, in which case tests shall be performed in accordance with 13.1.5 (see note 6). **A2**

Test I_t for fuse-links that exhibit take-over current(s) (see 13.1.2.4).

In the case of fuses which incorporate different arc-quenching mechanisms within the same envelope (e.g. current-limiting elements and expulsion elements in series), test duty 1, 2 and 3 above may need to be augmented by additional tests to prove correct operation in the region(s) of current I_t where the breaking duty is transferred from one arc-quenching mechanism to another.

It is not necessary to make breaking tests on fuse-links of all current-ratings of a homogeneous series; see 13.3 for the requirements to be met and tests to be made.

Also a homogeneous series can be approved without breaking tests by interpolation between the results of tests of related homogeneous series of fuse-links of higher and lower rated voltages; see 13.4 for the requirements to be met.

NOTE 1 Values of I_1 , I_2 and I_3 are the r.m.s. values of the a.c. component of the current.

NOTE 2 As a guide, the value of the current I_2 to comply with this requirement may be determined by one or other of the following methods:

a) From the following equation, if one test at a current 150 times the current rating or higher has been made under symmetrical fault initiation in test duty 1.

$$I_2 = I_1 \sqrt{\frac{i_1}{I_1}}$$

where

I_2 is the prospective current for test duty 2;

i_1 is the instantaneous current at instant of melting in test duty 1;

I_1 is the prospective current in test duty 1.

b) By taking between three and four times the current which corresponds to a pre-arcing time on one half-cycle on the time-current characteristic (see 14 and 18.9). If a time-current characteristic curve exists for virtual times less than one half-cycle, it is preferable to use the current corresponding on this time-current characteristic to a time of 0,08 normal half-cycle.

NOTE 3 If in making tests in accordance with test duty 2, the requirements of test duty 1 are completely met on one or more tests, then these tests need not be repeated as part of test duty 1.

NOTE 4 In very exceptional cases, the current I_2 may be higher than the rated maximum breaking current I_1 . Test duties 1 and 2 shall then be replaced by six tests at rated maximum breaking current with making angles as nearly as possible equally distributed with approximately 30° between each. (Parameters used will be those of test duty 2 (see Table 4) except making angle and value of instantaneous current at initiation of arcing.)

NOTE 5 If it is impossible in test duty 1, even by making at the earliest permissible angle, to initiate arcing as early as 65° after voltage zero, the requirement of one test with the initiation of arcing from 40° to 65° after voltage zero is replaced by an additional test (making a total of three) with initiation of arcing from 65° to 90° after voltage zero.

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NOTE 6 Some types of full-range fuses are designed specifically for use in conditions of high surrounding temperature, above the limits for normal service conditions, see 2.1a), for example inside a transformer tank. Such conditions may result in the fuse elements melting at a lower current than the fuse-link rated current. Special tests to take account of this onerous application are detailed in 13.1.5. Ⓐ

13.1.2 Characteristics of the test circuit

The breaking tests shall be made with single-phase alternating current and with single fuses.

The circuit elements used to control the current and power factor shall be in series relationship with each other and with the fuse, as shown in Figure 3 and Figure 4. No reactors shall be used that are subjected to saturation.

The test-circuit frequency shall be between 45 Hz and 62 Hz.

It is recommended that there shall be no distortion of the power-frequency recovery voltage that can readily be seen by inspection of the oscillogram.

Where some distortion is unavoidable, it shall not be such as to necessitate the open-circuit voltage to be more than 107 % of the voltage corresponding to the required recovery voltage on test duties 1 and 2, as specified in 13.1.1.

A cathode-ray oscillograph shall be provided for switching-voltage measurement during test duties 1 and 2. A cathode-ray oscillograph, a sphere-gap or a device of equivalent response shall be provided for switching-voltage measurement during test duty 3.

Switching-voltage protective equipment used in the test circuit shall be such that no spark-over occurs during the normal interrupting operation of the fuse, since a parallel path through protective equipment may reduce the duty on the fuse.

The prospective transient recovery voltage wave of the test circuit shall comply with the following two requirements:

Requirement a): its envelope shall at no time be below the specified reference line.

NOTE It is stressed that the extent by which the envelope may exceed the specified reference line requires the consent of the manufacturer (see the fourth paragraph of clause 8).

Requirement b): its initial portion shall not cross the specified delay line (if any).

These requirements are illustrated in Figure 9.

Standard values of reference and delay lines specified for the various test duties are as follows.

13.1.2.1 Test duty 1

In principle, the tests are to be made with the standardized values of TRV specified in 18.12. However, as stated in Annex B, current-limiting fuses are not sensitive to TRV characteristics, except when the highest arc voltage is reached immediately after initiation of the arc.

Consequently, for convenience of testing, the tests may be made as follows.

A first test will be made with any convenient prospective TRV and with initiation of arcing from 65° to 90° after voltage zero. If, during this test, the highest peak of arc voltage is not reached within a time equal to $2 t_3$ after initiation of arcing, this test is valid and the test duty 1 will be completed in the same circuit. Otherwise, the circuit shall be changed to provide a TRV with an envelope being at no time below the reference line specified in 18.12 and an initial portion not crossing the specified delay line. All the tests of test duty 1 shall be made in this new circuit.

13.1.2.2 Test duty 2

Tests shall be made with the values of prospective TRV specified in Table 3A and Table 3B (see Annex B).

The prospective TRV wave of the test circuit shall comply with the following requirements:

- a) its highest peak shall be not smaller than the parameter u_c specified;
- b) the rising segment of its envelope shall be between the two lines specified by the tolerance of t_3 .

NOTE A delay line is not specified, because the initial portion of the TRV wave is of no importance for the behaviour of the fuse (see Annex B).