

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**High-voltage fuses –
Part 1: Current-limiting fuses**

**Fusibles à haute tension –
Partie 1: Fusibles limiteurs de courant**



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Part 1: Current-limiting fuses**

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.120.50

ISBN 978-2-8322-8088-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE FUSES –

Part 1: Current-limiting fuses

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International Standard IEC 60282-1 has been prepared by subcommittee 32A: High-voltage fuses, of IEC technical committee 32: Fuses.

This eighth edition cancels and replaces the seventh edition published in 2009.

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

- additional information concerning thermally operated strikers;
- the division of ratings, characteristics and type tests into those applicable to all fuses and those applicable to particular fuse-link types and applications;
- adjustment of Series II voltages and tests to meet present North American standard system voltages and applications;
- clarification of requirements for fuse-links used in surrounding temperatures above 40 °C; and

- clarification of homogeneous requirements for fuse-links containing one element.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
32A/347/FDIS	32A/349/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts in the IEC 60282 series, published under the general title *High-voltage fuses*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

HIGH-VOLTAGE FUSES –

Part 1: Current-limiting fuses

1 Scope

This part of IEC 60282 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.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1, *Insulation coordination – Part 1: Definitions, principles and rules*

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

IEC 60644, *Specification for high-voltage fuse-links for motor circuit applications*

IEC 62271-105, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Electrical characteristics

3.1.1

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

Note 1 to entry: Examples of rated value usually stated for fuses: voltage, current and breaking current.

[SOURCE: IEC 60050-441:2000, 441-18-35, modified – "used for specification purposes" and "system" added, "assigned, generally by the manufacturer" deleted.]

3.1.2**rating**

set of rated values and operating conditions

[SOURCE: IEC 60050-441:2000, 441-18-36]

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

current that would flow in the circuit if the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: For the method to evaluate and to express the prospective current, see 7.6.2.1 and 7.6.2.2.

[SOURCE: IEC 60050-441:2000, 441-17-01, modified – deletion of "a switching device or", "each pole of the switching device or" and "is to be specified in the relevant publications" and addition of "see 7.6.2.1 and 7.6.2.2".]

3.1.4**prospective peak current**

peak value of a prospective current during the transient period following initiation

Note 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-17-02]

3.1.5**prospective breaking current**

RMS value of the AC component of the prospective current, evaluated at a specified time

Note 1 to entry: This specified time is given in 7.6.2.3.

3.1.6**breaking capacity**

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

[SOURCE: IEC 60050-441:2000, 441-17-08, modified – "switching device or a fuse" replaced with "fuse-link" and Notes removed.]

3.1.7**cut-off current****let-through current**

maximum instantaneous value of current attained during the breaking operation of a fuse

Note 1 to entry: 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 due to a current-limiting effect.

[SOURCE: IEC 60050-441:2000, 441-17-12, modified – "a switching device or" deleted, "due to a current limiting effect" added to Note 1 to entry.]

3.1.8**pre-arcing time****melting time**

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

[SOURCE: IEC 60050-441:2000, 441-18-21]

3.1.9**arcing time**

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

[SOURCE: IEC 60050-441:2000, 441-17-37, modified – references to "poles" removed.]

3.1.10**operating time****clearing time**

sum of the pre-arcing time and the arcing time

[SOURCE: IEC 60050-441:2000, 441-18-22]

3.1.11 **I^2t** **Joule integral**

integral of the square of the current over a given time interval $t_0 - t_1$

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

Note 1 to entry: The pre-arcing I^2t is the I^2t integral extended over the pre-arcing time of the fuse.

Note 2 to entry: The operating I^2t is the I^2t integral extended over the operating time of the fuse.

Note 3 to entry: The energy in joules liberated in 1 Ω of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in $A^2 \times s$.

[SOURCE: IEC 60050-441:2000, 441-18-23]

3.1.12**virtual time**

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

Note 1 to entry: The values of virtual times usually stated for a fuse-link are the values of pre-arcing time and of operating time.

[SOURCE: IEC 60050-441:2000, 441-18-37]

3.1.13**time-current characteristic**

curve giving the virtual time, for example pre-arcing time or operating time, as a function of the prospective current under stated conditions of operation

[SOURCE: IEC 60050-441:2000, 441-17-13, modified – "virtual" added.]

3.1.14**cut-off (current) characteristic****let-through (current) characteristic**

curve giving the cut-off current as a function of the RMS prospective current, under stated conditions of operation

Note 1 to entry: The values of the cut-off currents are the maximum values that can be reached whatever the degree of asymmetry.

[SOURCE: IEC 60050-441:2000, 441-17-14, modified – "RMS" added, and references relating to direct currents removed from the note to entry.]

3.1.15**recovery voltage**

voltage which appears across the terminals of a fuse after the breaking of the current

Note 1 to entry: 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 recovery voltage alone exists.

[SOURCE: IEC 60050-441:2000, 441-17-25, modified – "a pole of a switching device or" removed and "or the steady-state" removed from the Note to entry.]

3.1.16**transient recovery voltage**

TRV

recovery voltage during the time in which it has a significant transient character

Note 1 to entry: 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 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-17-26, modified – "switching device" and "pole" replaced by "fuse" in the Notes to entry.]

3.1.17**power-frequency recovery voltage**

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:2000, 441-17-27]

3.1.18**prospective transient recovery voltage** (of a circuit)

transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

Note 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-17-29, modified – "switching device or" removed from note to entry.]

3.1.19**switching voltage**

maximum instantaneous value of voltage which appears across the terminals of a fuse during its operation

Note 1 to entry: The switching voltage may be the arc voltage or may occur during the time of transient recovery voltage.

[SOURCE: IEC 60050-441:2000, 441-18-31]

3.1.20**minimum breaking current**

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

[SOURCE: IEC 60050-441:2000, 441-18-29]

3.1.21

power dissipation (in a fuse-link)

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

Note 1 to entry: Prescribed conditions of use and behaviour generally include a constant RMS value of the electric current after steady-state temperature conditions are reached.

[SOURCE: IEC 60050-441:2000, 441-18-38]

3.1.22

maximum breaking current

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

3.1.23

lightning impulse

voltage pulse of a specified shape applied during dielectric tests with a virtual front duration of the order of 1 µs and a time to half value of the order of 50 µs

Note 1 to entry: The lightning impulse is defined by the two figures giving these durations in microseconds; in particular the standard lightning impulse is 1,2/50 µs.

[SOURCE: IEC 60050-614:2016, 641-03-28]

3.1.24

rated lightning impulse withstand voltage

designated maximum peak withstand-voltage value, of a lightning impulse voltage wave, that is assigned to the device regarding its ability to withstand a lightning impulse voltage

Note 1 to entry: The term previously used is "basic impulse insulation level (BIL)" (still in common usage).

3.2 Fuses and their component parts

3.2.1

fuse

device that by the fusing of one or more of its specially designed and proportioned components, opens the circuit to which it is connected 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

[SOURCE: IEC 60050-441:2000, 441-18-01, modified – "in which it is inserted" changed to "to which it is connected".]

3.2.2

terminal

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

Note 1 to entry: Terminals may be distinguished according to the kind of circuits for which they are intended (for example, main terminal, earth terminal, etc.), but also according to their design (for example, screw terminal, plug terminal, etc.).

3.2.3

fuse-base

fuse-mount

fixed part of a fuse provided with contacts and terminals

Note 1 to entry: The fuse-base comprises all the parts necessary for insulation (see Figure 1).

[SOURCE: IEC 60050-441:2000, 441-18-02, modified – Note 1 to entry added.]

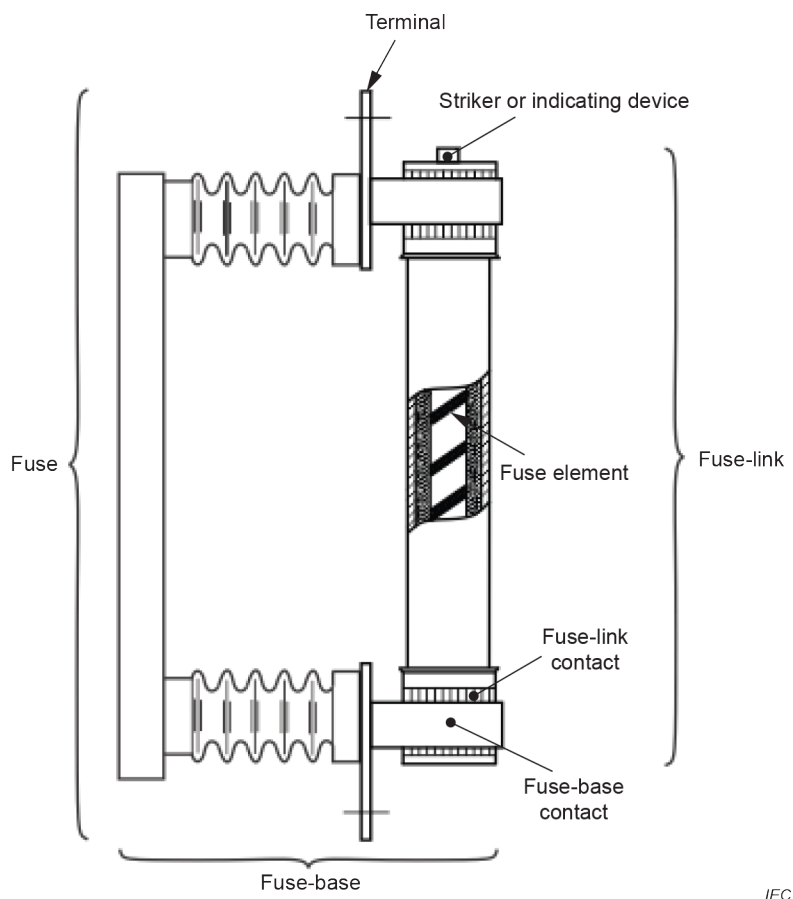


Figure 1 – Terminology

3.2.4

fuse-base contact

contact piece of a fuse-base designed to engage with a fuse-link contact (see Figure 1)

[SOURCE: IEC 60050-441:2000, 441-18-03, modified – "corresponding part of the fuse" replaced with "fuse-link contact (see Figure 1)".]

3.2.5

fuse-link

part of a fuse (including the fuse element(s)) intended to be replaced after the fuse has operated (see Figure 1)

[SOURCE: IEC 60050-441:2000, 441-18-09, modified – "see Figure 1" added.]

3.2.6

fuse-link contact

contact piece of a fuse-link designed to engage with a fuse-base contact (see Figure 1)

[SOURCE: IEC 60050-441:2000, 441-18-04, modified – "corresponding part of the fuse" replaced with "fuse-base contact (see Figure 1)".]

3.2.7

fuse-element

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)

[SOURCE: IEC 60050-441:2000, 441-18-08 modified – "(see Figure 1)" added.]

3.2.8 indicating device indicator

part of a fuse provided to indicate whether the fuse has operated (see Figure 1)

[SOURCE: IEC 60050-441:2000, 441-18-17, modified – "(see Figure 1)" added.]

3.2.9 striker

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

[SOURCE: IEC 60050-441:2000, 441-18-18]

3.2.10 thermally operated striker

mechanical device forming part of a fuse-link which, when released by fuse operation or specific thermal conditions in the fuse-link, releases the energy required to cause operation of other apparatus or indicators or to provide interlocking

3.3 Additional terms

3.3.1 current-limiting fuse

fuse 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

[SOURCE: IEC 60050-441:2000, 441-18-10, modified – "fuse-link" replaced by "fuse".]

3.3.2 classes

definitions of current-limiting fuses according to the range in which they can be used, divided as follows:

- Back-Up fuses
- General-Purpose fuses
- Full-Range fuses

SEE IEC TR 62655:2013, 4.2.2

3.3.3 Back-Up fuse

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

3.3.4 General-Purpose fuse

current-limiting fuse capable of breaking, under specified conditions of use and behaviour, all currents from the rated maximum breaking current down to a low value equal to the current that causes melting of the fuse element in 1 h

3.3.5 Full-Range fuse

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

SEE 7.6.1.1, test duty 3

3.3.6

isolating distance (for a fuse-base)

shortest distance between the fuse-base contacts or any conductive parts connected thereto, measured on a fuse with the fuse-link removed

[SOURCE: IEC 60050-441:2000, 411-18-06, modified – "or fuse-carrier" removed.]

3.3.7

homogeneous series (of fuse-links)

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 7.6.4.1

[SOURCE: IEC 60050-441, 441-18-34, modified – Note removed, "SEE 7.6.4.1" added.]

3.3.8

external insulation

distances in atmospheric air and along 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 environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin, etc.

[SOURCE: IEC 60050-614:2016, 614-03-02]

3.3.9

self-restoring insulation

insulation which completely recovers its insulating properties within a short time interval after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.3.10

organic fuse-link

fuse-link that contains a significant proportion of organic (e.g. carbon based) material that could be a possible cause of excessive leakage current following fuse operation

Note 1 to entry: If the manufacturer determines that the location and quantity of organic or other material in a design might lead to excessive post-operation leakage current and breakdown, the manufacturer shall designate the fuse-link as "organic".

3.3.11

surrounding temperature

temperature of the gaseous or liquid dielectric surrounding the fuse-link.

3.3.12

fuse-enclosure package

FEP

enclosure supplied with one or more fuse-links as a complete package and where application data covering the specific fuse-link(s) and enclosure is available.

Note 1 to entry: Depending on the particular application, the fuse-links(s) also may or may not be mounted in a canister that is then assembled into the enclosure.

3.3.13

canister

fuse-container

small fuse enclosure package consisting of a close-fitting container that supports a fuse-link and restricts the air, gas, or liquid flow surrounding it

4 Normal and special service conditions

4.1 Normal service conditions

Fuses complying with this document 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 1 The time-current characteristics of fuses will be modified between the minimum and maximum temperatures.

- b) The altitude does not exceed 1 000 m.
- 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 hPa;
 - the average value of the relative humidity, for a period of one month, does not exceed 90 %;
 - the average value of the water vapour pressure, for a period of one month, does not exceed 18 hPa.

In these conditions, condensation may occasionally occur.

NOTE 2 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 3 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 are an alternative.

NOTE 4 Condensation is 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 solar radiation does not exceed 1,0 kW/m².

Applications involving fuse-links in enclosures (fuse enclosure packages) typically satisfy the requirements of "normal service conditions" because the ambient temperature (the temperature outside the enclosure) meets the temperatures in a) of this subclause. However, in an enclosure, surrounding temperatures (see 3.3.11) above 40 °C are to be expected and additional considerations may apply regarding assigning a current carrying capability to the device (see 5.3.6, 5.3.7, 5.2.7.2 and IEC TR 62655:2013).

For certain fuse-links and applications in enclosures additional tests may be required as covered in this document in Annex E.

4.2 Special service conditions

4.2.1 General

By agreement between the manufacturer and the user, high-voltage fuses may be used under conditions different from the normal service conditions given in 4.1. For any special service condition, the manufacturer shall be consulted.

4.2.2 Altitude

For installations at an altitude higher than 1 000 m, the required rated insulation withstand level of external insulation shall be determined by multiplying the needed insulation levels at the service location by an altitude correction factor, K_a (> 1) given in column (2) of Table 1. The dielectric withstand voltages of a fuse at a particular altitude may be determined by multiplying its rated insulation withstand levels by $1/K_a$ (< 1), given in column (3) of Table 1.

For altitudes between 1 000 m and 1 500 m and between 1 500 m and 3 000 m, the correction factors may be obtained by linear interpolation between the values in Table 1.

Table 1 – Altitude correction factors – Dielectric withstand

Maximum altitude m (1)	Correction factor for withstand voltages (K_a) (2)	Correction factor applied to rated withstand voltages ($1/K_a$) (3)
1 000	1,0	1,0
1 500	1,05	0,95
3 000	1,25	0,80

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

The current-carrying capability of a fuse may be determined for altitudes exceeding 1 000 m by applying the appropriate factors given in Table 2, column (2) to the rated current or allowable continuous current of the fuse.

For altitudes between 1 000 m and 1 500 m and between 1 500 m and 3 000 m, the correction factors may be obtained by linear interpolation between the values in Table 2.

Table 2 – Altitude correction factors – Current-carrying capability

Maximum altitude m (1)	Correction factor for current-carrying capability (2)
1 000	1,0
1 500	0,99
3 000	0,96

4.3 Environmental behaviour

Fuses complying with this document are inert devices during normal service. It is also a requirement of 6.1.3 that no significant external emission takes place. Therefore, they are regarded as environmentally safe devices in service and operation.

5 Ratings and characteristics

5.1 General

- a) Ratings of the fuse-base
 - 1) Rated voltage (5.2.1)
 - 2) Rated current (5.2.2)
 - 3) Rated insulation level (power-frequency, dry, wet and lightning impulse withstand voltages) (5.2.4)
- b) Ratings of the fuse-link
 - 1) Rated voltage (5.2.1)
 - 2) Rated current (5.2.3)
 - 3) Rated maximum breaking current (5.2.5.1)
 - 4) Rated minimum breaking current for Back-Up fuses (5.2.5.2)
 - 5) Rated frequency (5.2.6)
- c) Characteristics of the fuse
 - 1) Temperature rise limits (5.2.7)
- d) Characteristics of the fuse-link
 - 1) Class (3.3.2 and 5.2.5.2)
 - 2) Switching voltages (5.2.8)
 - 3) Time-current characteristics (5.2.9)
 - 4) Cut-off characteristics (5.2.10)
 - 5) I^2t characteristics (5.2.11)
 - 6) Power dissipation (5.2.12)
- e) Ratings and characteristics of particular fuse-link types and applications
 - 1) Striker mechanical characteristics (5.3.4.3)
 - 2) K Factor (for fuse-links for motor circuit applications) (See IEC 60644)
 - 3) Maximum application temperature (see Annex E)
 - 4) Allowable continuous current (5.3.6)
 - 5) Maximum enclosure current (5.3.7)

5.2 Ratings and characteristics that are applicable to all fuses

5.2.1 Rated voltage (U_r)

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

NOTE See 6.1.2 for details on the relationship between a fuse rated voltage and the voltage of the system on which it may be used, based on the system assumptions and the specifications used for the fuse-link breaking tests.

The rated voltage of a fuse should be selected from the voltages given in Table 3. The two sets of values, series I and series II are based on common practice in different parts of the world (series II is based on North American practice).

Table 3 – Rated voltages

Series I	Series II
kV	kV
3,6	2,8
7,2	5,5
12	8,3
17,5	15,5
24	17,2
36	23
40,5	27
52	38
72,5	48,3
	72,5

5.2.2 Rated current of a fuse-base

The current assigned to a fuse-base that a new clean fuse-base will carry continuously without exceeding specified temperature rises under prescribed conditions. These conditions are that the fuse-base is equipped with a fuse-link designed to be used in the particular fuse-base, that the fuse-link has a rated current the same as the rated current of the fuse base, that the fuse-base is connected to the circuit with conductors of certain specified sizes and lengths, and that the ambient air temperature is not more than 40 °C.

The rated current of a fuse-base should be selected from the following values:

10 A; 25 A; 63 A; 100 A; 200 A; 400 A; 630 A; 1 000 A.

5.2.3 Rated current of a fuse-link (I_r)

The current assigned to a 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 IEC TR 62655:2013).

The rated current in amperes of the fuse-link should be selected from the R10 series. For special cases, additional values for the rated current of the fuse-link may be selected from the R20 series.

NOTE The R10 series comprises the numbers 1; 1,25; 1,6; 2; 2,5; 3,15; 4; 5; 6,3; 8 and their multiples of 10. The R20 series comprises the numbers 1; 1,12; 1,25; 1,40; 1,6; 1,8; 2; 2,24; 2,5; 2,8; 3,15; 3,55; 4; 4,5; 5; 5,6; 6,3; 7,1; 8; 9 and their multiples of 10.

5.2.4 Rated insulation level (of a fuse-base)

The voltage values (both power frequency and impulse) that characterise the insulation of a fuse-base with regard to its capability of withstanding dielectric stresses (see IEC TR 62655:2013, 4.5) under normal service conditions defined in 4.1 including altitudes from sea level up to 1 000 m.

Two levels of dielectric withstand are recognised 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 IEC TR 62655:2013, 4.5.2).

The rated insulation level of a fuse-base should be selected from Table 4 and Table 5.

- Table 4 is based on practice in Europe, and standard reference conditions of temperature, pressure and humidity are 20 °C, 101,3 kPa and 11 g/m³, respectively, of water.
- Table 5 is based on practice in the USA and Canada where standard reference conditions of temperature, pressure and humidity are 25 °C, 101,3 kPa and 15 g/m³, respectively, of water.

It shall be stated whether the fuse is suitable for indoor or outdoor service.

Table 4 – Fuse-base rated insulation levels – Series I

Rated voltage of the fuse kV	Rated lightning impulse withstand voltage (negative and positive polarity)				Rated 1 min power-frequency withstand voltage	
	List 1 (peak value) kV		List 2 (peak value) kV		(dry and wet) (RMS value) kV	
	To earth and between poles	Across the isolating distance of the fuse-base ^a	To earth and between poles	Across the isolating distance of the fuse-base ^a	To earth and between poles	Across the isolating distance of the fuse-base ^a
3,6	20	23	40	46	10	12
7,2	40	46	60	70	20	23
12	60	70	75	85	28	32
17,5	75	85	95	110	38	45
24	95	110	125	145	50	60
36	145	165	170	195	70	80
40,5	180	200	190	220	80	95
52	250	290	250	290	95	110
72,5	325	375	325	375	140	160

^a An isolating insulation level should be specified only for those fuse-bases to which isolating properties are assigned.

Table 5 – Fuse-base rated insulation levels – Series II

Rated voltage of the fuse kV	Rated lightning impulse withstand voltage (negative and positive polarity)				Rated power-frequency withstand voltage					
	(peak value) kV				(RMS value) kV					
	To earth and between poles		Across the isolating distance of the fuse-base ^a		To earth and between poles			Across the isolating distance of the fuse-base ^a		
	Indoor	Outdoor	Indoor	Outdoor	Indoor 1 min dry	Outdoor		Indoor 1 min dry	Outdoor	
2,8	45	–	50	–	15	–	–	17	–	–
5,5	60	–	66	–	19	–	–	21	–	–
8,3	75	95	83	105	26	35	30	29	39	33
15,5 to 17,2	95	–	105	–	36	–	–	40	–	–
15,5 to 17,2	110	110	121	121	50	50	45	55	55	50
23 to 27	125	150	138	165	60	70	60	66	77	66
23 to 27	150	–	165	–	60	–	–	66	–	–
38	150	200	165	220	70	95	80	77	105	88
48,3	–	250	–	275	–	120	100	–	132	110
72,5	–	350	–	385	–	175	145	–	193	160

^a An isolating insulation level should be specified only for those fuse-bases to which isolating properties are assigned.

5.2.5 Rated breaking capacity

5.2.5.1 Rated maximum breaking current (I_1)

The rated maximum breaking current in kA of a fuse-link should be selected from the R10 series.

NOTE The R10 series comprises the numbers 1; 1,25; 1,6; 2; 2,5; 3,15; 4; 5; 6,3; 8 and their multiples of 10.

5.2.5.2 Rated minimum breaking current and class

The manufacturer shall indicate the class (see 3.3.2) and, for Back-Up fuses, the rated minimum breaking current. In the case of General-Purpose fuses, the minimum breaking current may also be indicated.

5.2.6 Rated frequency

Standard values of rated frequency are 50 Hz and 60 Hz. It should be noted that fuses are normally tested at either 50 Hz or 60 Hz. However, experience has shown that, while the same fuse design tested at both frequencies at a current that produces a current-limiting action generally exhibits slightly higher peak currents at 60 Hz and slightly higher operating I^2t values at 50 Hz, fuses successfully passing all testing at one frequency are suitable for use at the other frequency.

5.2.7 Temperature limits

5.2.7.1 Surrounding temperature of 40 °C or less

A fuse-link and a fuse-base shall be able to carry their rated current continuously without exceeding the limits of temperature rise (above ambient temperature) given in Table 6, and without deterioration.

Where engaging contact surfaces have different coatings, the permissible temperatures and temperature rises shall be as follows:

- a) for bolted contacts and terminals, those of the component having the highest values permitted in Table 6;
- b) for spring-loaded contacts, those of the component having the lowest values permitted in Table 6.

5.2.7.2 Surrounding temperature above 40 °C

When a fuse-link is in an enclosure (FEP), or at elevated ambient temperature, and the surrounding temperature of the fuse-link or canister is above 40 °C, the fuse may be assigned an allowable continuous current at a specified surrounding temperature. A fuse-link and a fuse-base shall be able to carry an assigned allowable continuous current, at a specified surrounding temperature, continuously without exceeding the limits of maximum temperature given in Table 6.

When it is not possible to assign an allowable continuous current (at high surrounding temperatures and with the fuse-link in liquid), a maximum enclosure current (I_{fep}) may be specified. In this case, the maximum values of temperature given in Table 6 may be exceeded by agreement between the manufacturer and user.

NOTE For fuses used in enclosures, see IEC TR 62655:2013, 5.1.1.2 and Annex A.

Table 6 – Limits of temperature and temperature rise for components and materials

Component or material	Maximum value of	
	Temperature °C	Temperature rise K
A Contacts in air:		
1 Spring-loaded contacts (copper or copper alloy)		
– bare	75	35
– silver- or nickel-coated	105	65
– tin-coated	95	55
– other metal coatings ^a		
2 Bolted contacts or equivalent (copper, copper alloy and aluminium alloy)		
– bare	90	50
– tin-coated	105	65
– silver- or nickel-coated	115	75
– other metal coatings ^a		
B Contacts in insulating liquid (copper or copper alloy):		
1 Spring-loaded contacts		
– bare	80	40
– silver-, tin- or nickel-coated	90	50
– other metal coatings ^a	-	-
2 Bolted contacts		
– bare	100	60
– silver-, tin- or nickel-coated	100	60
– other metal coatings ^a	-	-
C Bolted terminals in air:		
– bare	90	50
– silver-, nickel- or tin-coated	105	65
– other metal coatings ^a	-	-
D Metal parts acting as springs^b		
	-	-
E Materials used as insulation and metal parts in contact with insulation of following classes^c:		
Class Y (for non-impregnated materials)	90	50
Class A (for materials immersed in insulating liquid) ^f	100	60
Class E	120	80
Class B	130	90
Class F	155	115
Enamel: oil base	100	60
synthetic	120	80
Class H	180	140
Other classes ^d		-
F Insulating liquid for switchgear type applications^{e, f}		
	90	50
G Any part of metal or of insulating material in contact with insulating liquid^f except contacts and springs		
	100	60
^a If the manufacturer uses coatings other than those indicated in Table 6, the properties of these materials should be taken into consideration. ^b The temperature or the temperature rise should not reach such a value that the elasticity of the metal is impaired. ^c Classes generally according to IEC 60085. ^d Limited only by the requirement not to cause any damage to surrounding parts. ^e Measured at the upper part of the liquid. ^f Special consideration should be given with regard to vaporisation and oxidation when low-flash-point insulating liquid is used. The quoted values are for oil; the given temperature values may be exceeded for transformer-type applications and/or if synthetic or other suitable insulating liquids are used (see 8.3.4.3 and IEC 60076-7).		

5.2.8 Limits of switching voltage

The value of switching voltages during operation in all test duties shall not exceed those given in Table 7 and Table 8.

On request, the manufacturer shall indicate the maximum value of the switching voltages as determined in the breaking tests (see 7.6).

Table 7 – Maximum permissible switching voltages

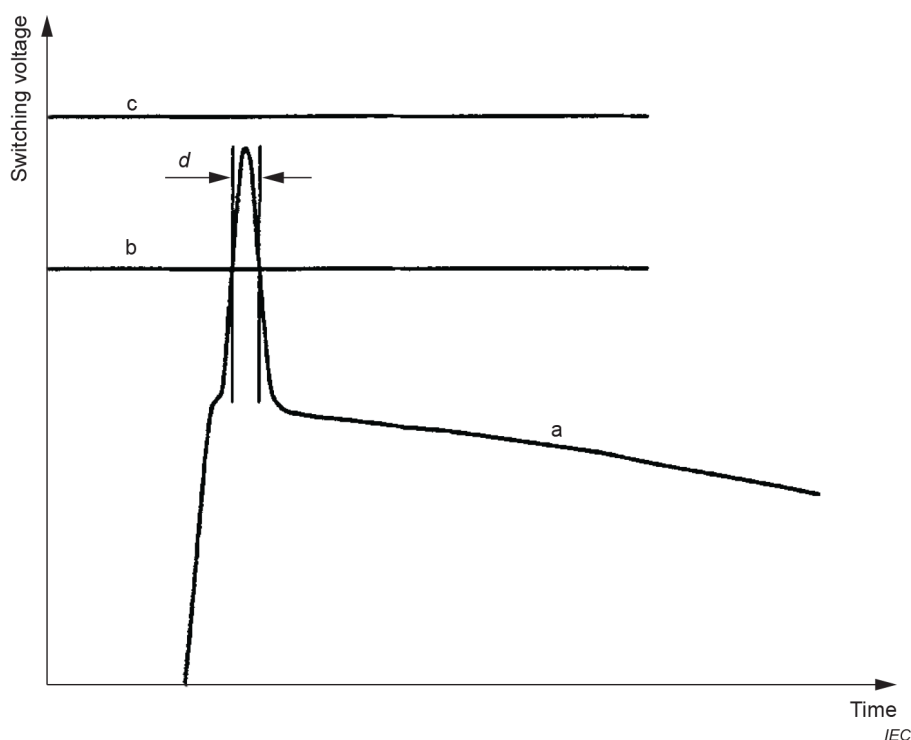
Series I		Series II	
Rated voltage kV	Maximum switching voltage kV	Rated voltage kV	Maximum switching voltage kV
3,6	12	2,8	9
7,2	23	5,5	18
12	38	8,3	26
17,5	55	15,5 to 17,2	49
24	75	23	72
36	112	27	84
40,5	126	38	119
52	162	48,3	150
72,5	226	72,5	226

Table 8 – Maximum permissible switching voltages for certain fuse-links of small current ratings

Series I up to and including 12,5 A		Series II up to and including 12 A	
Rated voltage kV	Maximum switching voltage ^{a, b} kV	Rated voltage kV	Maximum switching voltage ^a kV
3,6	26	2,8	13
7,2	36	5,5	25
12	50	8,3	38
17,5	63	15,5 to 17,2	70
24	85	23	105
36	120	27	123
		38	173

^a For equipment with rated voltages of series I, switching voltages specified in Table 8 are permissible for associated rated lightning impulse withstand voltages of List 2 only (see 5.2.4).

^b The switching voltage values may exceed the limits given in Table 7 for a duration not exceeding 200 µs but shall not exceed the limits given in Table 8 (see Figure 2).



Key

- a Switching-voltage curve
- c Switching-voltage limit – Table 8
- b Switching-voltage limit – Table 7
- d $\leq 200 \mu\text{s}$

Figure 2 – Permissible switching voltages for fuse-links of small current ratings (Table 8)

5.2.9 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 conductors having sizes and lengths as specified in 7.5.1.2.

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

The manufacturer shall make available curves from the data determined by the time-current characteristics type tests specified in 7.7.2.

The time-current characteristics shall be presented with current as abscissa and time as ordinate.

Logarithmic scales shall be used on both coordinate axes. The basis of the logarithmic scales (the dimensions of one decade) shall be in the ratio 2:1 with the longer dimension on the abscissa. However, because of long-established practice in the USA, a ratio of 1:1 (5,6 cm) is recognised as an alternative standard.

The representation shall be made on standardised paper A3 or A4, or according to the USA standard.

The dimensions of the decades shall be selected from the following series:

2 cm; 4 cm; 8 cm; 16 cm and 2,8 cm; 5,6 cm; 11,2 cm.

It is recommended to use 2,8 and 5,6, wherever possible.

The curves shall show

- the relation between the virtual pre-arcing time and the prospective current;
- the basis of current, whether mean or minimum. If mean current values are used, the tolerance shall not exceed ± 20 %. If minimum values are used, the tolerance shall not exceed +50 %;
- the type and current rating of the fuse-link to which the curve data apply;
- the time range as specified in 7.7.2.2. For Back-Up fuses, a dotted line shall be plotted from minimum breaking current to 600 s if the minimum breaking current corresponds to a time less than 600 s.

5.2.10 Cut-off characteristic

The manufacturer shall indicate the upper limit of the cut-off current corresponding to each value of prospective breaking current up to the rated maximum breaking current of the fuse under specified conditions determined as part of the breaking type tests specified in 7.6.

It shall be stated whether the characteristic applies to 50 Hz or 60 Hz.

5.2.11 I^2t characteristics

The manufacturer shall make available values of operating I^2t and pre-arcing I^2t for those prospective currents for which the fuse exhibits cut-off characteristics.

Values stated for the operating I^2t shall represent the highest values likely to be experienced in service. These values shall refer to the test conditions of this document, for example, the values of voltage, frequency and power factor.

Values stated for the pre-arcing I^2t shall represent the lowest values likely to be experienced in service.

The presentation of I^2t values may be in simple tabular or diagrammatic form (for example, histograms) or may employ graphical presentation with prospective current as abscissa and I^2t as ordinate, both scales being logarithmic with preferred dimensions as in 5.2.9.

The I^2t values determined as a part of the breaking type tests specified in 7.6 shall not be greater (for operating I^2t) or less (for pre-arcing I^2t) than the values stated by the manufacturer.

5.2.12 Power dissipation

The manufacturer shall make available values of power dissipation of a fuse-link at 50 % and 100 % of the rated current of the fuse-link (see 7.5.3).

5.3 Ratings and characteristics of particular fuse-link types and applications

5.3.1 Fuse-links for transformer applications

While fuse-links are most commonly used for transformer applications, there are no special characteristics specified. However, there are many application recommendations, generally relating to a fuse-link's time-current characteristics, and these can be found in IEC TR 62655:2013.

5.3.2 Fuse-links for motor circuit applications

Special characteristics for fuse-links for motor circuit applications are found in IEC 60644, as well as additional testing requirements.

5.3.3 Fuse-links for capacitor protection

Current-limiting fuse-links for capacitor protection have no special characteristics specified, but they are tested in accordance with this document and with additional testing requirements covered by IEC 60549.

5.3.4 Fuses fitted with indicating devices

5.3.4.1 General

Fuses may be fitted with devices to indicate that they have operated (melted and/or interrupted or in the case of a thermally triggered device, reached the triggering temperature). Devices covered by this document include indicators and strikers that are an integral part of a fuse-link. An indicator merely gives visual indication of fuse operation and provides no guaranteed force to operate auxiliary devices (such as tripping a series connected switch). A striker has a defined force/distance profile and is usually used to trip an auxiliary device.

The correct operation of the striker in combination with the tripping mechanism of the switching device is outside the scope of this document; see IEC 62271-105.

5.3.4.2 Indicator characteristics

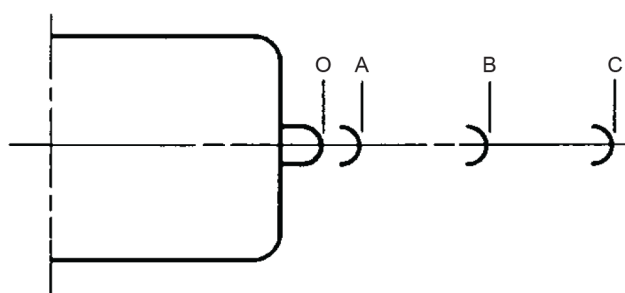
There are no specific characteristic requirements for an indicator, other than it should be readily visible that the indicator has deployed after a fuse operation.

5.3.4.3 Striker mechanical characteristics

Three types of striker, light, medium, and heavy, are classified by the amount of energy they are able to deliver to a mechanical switching device, or a signalling device, between two points A and B (see Figure 3) of their travel and, for medium and heavy types, by a minimum withstand force. The withstand force is the characteristic which prevents the return of the striker, after operation, to less than the minimum actual travel (OB) when a static external force is applied.

NOTE A striker normally performs the function of an indicator.

The mechanical characteristics of the strikers are given in Table 9.



IEC

Key

- OA Free travel – No energy output specified
- AB Further travel during which the specified energy shall be delivered
- OB Minimum actual travel
- OC Maximum actual travel
- CB Maximum permitted return travel under withstand force (when applicable)

Figure 3 – Various stages of the striker travel**Table 9 – Striker mechanical characteristics**

Type	Energy	Mechanical characteristics					
		Values of		Actual travel		Minimum withstand force	Maximum duration of travel ^b
		Free travel (OA) ^a	Further travel during which energy shall be delivered (AB) ^a	Min. (OB) ^a	Max. (OC) ^a		
	J	mm	mm	mm	mm	N	ms
Light	0,3 ± 0,25	2	8	10	30	Not applicable	50
Medium	1 ± 0,5	4	16	20	40	20	50
Heavy	2 ± 1	4	6	10	16	40	50

^a See Figure 3.

^b Duration of travel is defined as the time from commencement of arcing to the time when travel OB is reached. The minimum arcing withstand time of 100 ms (5.3.5.3) is sufficient to cover this 50 ms plus an additional time of 50 ms to allow for the switching device operating time.

5.3.4.4 Thermally operated strikers

Thermally operated strikers are used as a method of reducing fuse temperatures before electrical striker operation, primarily at lower currents. It is possible for a thermally operated striker to operate with the main fuse elements still intact. They are normally used in fuse enclosure packages (particularly in canisters), and because of the different designs and materials used, the different relative positions of the fuse (e.g. horizontal or vertical) and different fuse sizes, it is not possible to specify any limiting values for operating time or tripping temperature.

The mechanical characteristics of the strikers according to 5.3.4.3 are also valid for thermal strikers.

5.3.5 Back-Up fuses intended for use in a switch-fuse combination according to IEC 62271-105

5.3.5.1 General

For such applications, it is necessary to ensure that

- a) when installed in its service environment, the fuse is able to withstand currents below minimum breaking current during the pre-arcing phase (i.e. just prior to actual fuse melting) without thermal damage to itself or its surroundings;
- b) the fuse arcing withstand time without damage (see 5.3.5.3 and 8.3.3.3) at currents just below fuse minimum breaking current is longer in duration than the tripping time of the associated switch.

5.3.5.2 Maximum body temperature under pre-arcing conditions

For Back-Up fuses intended for use in striker-tripped fuse-switch combinations according to IEC 62271-105, the fuse manufacturer shall define the maximum body temperature that may be reached with any current above the minimum melting current, and the corresponding current value.

A procedure to determine this temperature and current value is given in 8.3.3.2. In the case of homogeneous series, it is sufficient to perform the test on the fuse having the highest current rating.

5.3.5.3 Maximum arcing withstand time

The arcing withstand time is the time between the beginning of the arcing and the occurrence of external damage to the fuse. The fuse manufacturer shall provide information regarding the maximum arcing withstand time, at a current value between 70 % and 100 % of rated minimum breaking current.

This time shall be at least 0,1 s. The testing procedure is described in 8.3.3.3.

5.3.6 Allowable continuous current of a fuse-link (I_a)

The current assigned to a fuse-link that a new clean fuse-link will carry continuously, at a specified surrounding temperature, without exceeding specified maximum temperatures when mounted as specified by the manufacturer. The surrounding temperature may exceed 40 °C (see IEC TR 62655:2013).

NOTE It is possible for allowable continuous current values to be higher than, equal to, or lower than the assigned rated current (I_r). For example, higher values of allowable continuous current are primarily associated with certain fuse designs, while the more usual situation of lower values of allowable continuous current are normally associated with elevated surrounding temperatures and/or specific application conditions. It is also possible for a particular fuse-link to have several allowable continuous currents specified (e.g. each at a different surrounding temperature) or to have allowable continuous current defined by a formula related to surrounding temperature.

5.3.7 Maximum enclosure current (I_{fep})

The current assigned to a fuse-link by the FEP manufacturer that a new clean fuse-link will carry continuously, at a specified surrounding temperature above 40 °C, when mounted as specified by the manufacturer and immersed in liquid. A fuse-link will have multiple values of I_{fep} depending on the enclosure and surrounding temperature. (See IEC/TR 62655:2013.) The maximum values of temperature given in Table 6 may be exceeded, but only by agreement between the manufacturer and user. The maximum enclosure current is used for the liquid tightness test (8.3.4).

6 Design, construction and performance

6.1 General requirements with respect to fuse operation

6.1.1 General

When used in systems with service voltages less than the rated voltage of the fuse, the maximum breaking current 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 7.6 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 IEC TR 62655:2013).

6.1.2 Standard conditions of use

Testing specified in this document is intended to demonstrate the suitability of a fuse for use under the following conditions:

- a) the AC component of current is not higher than the rated maximum breaking current;
- b) the AC component of a current that the fuse is intended to interrupt is not lower than:
 - the rated minimum breaking current for a Back-Up fuse;
 - the current that causes melting in 1 h for a General-Purpose fuse;
 - the rated current for a Full-Range fuse;
- c) the surrounding temperature is not higher than the maximum application temperature (MAT), for fuses that have been assigned a MAT. In the case of a Full-Range fuse that has an assigned MAT, there is no low current restriction;
- d) the highest system voltage is not greater than the rated voltage of the fuse-link, if used in a three-phase solidly earthed neutral system or low impedance – or low resistance-earthed neutral system;
- e) the highest system voltage is not greater than 87 % of the rated voltage of the fuse-link, if used in a three-phase isolated neutral system or a resonant earthed system and the fuse-links have been tested to Series I voltage in accordance with Table 11. This is because a double earth fault (with one fault on the supply side and one fault on the load side of a fuse on another phase) can occur.

It may be noted that a higher maximum system voltage than 87 % of the rated voltage of the fuse-link is acceptable when additional or alternative tests have been performed on the fuse (see IEC TR 62655:2013, 5.1.3.3);

- f) the highest single-phase voltage to which the fuse-link is subjected during and after current interruption is not greater than 87 % of the rated voltage of the fuse-link, if used on a single-phase application and the fuse-links have been tested to a Series I voltage and in accordance with Table 11.

It may be noted that a higher maximum voltage than 87 % of the rated voltage of the fuse-link is acceptable when additional or alternative tests have been performed on the fuse (see IEC TR 62655:2013, 5.1.3.3);

- g) the highest system voltage on a three-phase system or single-phase voltage on a single-phase application is not greater than the rated voltage of the fuse-link, if the fuse-link has been tested to a Series II voltage and in accordance with Table 11, footnote b;
- h) the prospective transient recovery voltage is within the limits represented by the tests specified in 7.6.1.4;
- i) the frequency is between 48 Hz and 62 Hz;

- j) the power factor is not lower than specified in Table 11;
- k) 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 7.6.1.4.

NOTE 3 As regards the prospective TRV characteristics, the time coordinate 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 7.6.1.5.3).

It is considered that fuses will be capable of breaking correctly any value of prospective current, irrespective of the possible DC component, provided that the preceding requirements have been met.

6.1.3 Standard conditions of behaviour

According to the conditions of use indicated in 6.1.2, the behaviour of the fuse shall be as follows.

- a) A fuse-link using arc extinguishing material shall not emit flame or arc extinguishing material, 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.
- 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 5.3.4.3 and shall operate fully;
 - 3) the operation of a thermal striker before fuse-element melting during a Test Duty 3 test shall not be considered a fuse failure.
- d) Operation shall not generate switching voltages higher than the values specified in 5.2.8.
- 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.

6.2 Identifying markings

The identifying markings which shall be indelibly marked on fuse-links and fuse-bases are given below.

It may be noted that when the physical dimensions of the fuse-link are so small as to make it impossible for such markings to include the indications given below, alternative methods may be adopted.

The figures representing ratings shall, in all cases, be followed by the symbol of the unit in which they are expressed.

- a) On the fuse-base
 - manufacturer's name or trade mark;
 - manufacturer's type designation;
 - rated voltage;
 - rated current.

b) On the fuse-link

- manufacturer's name or trade mark;
- manufacturer's type designation;
- rated voltage;
- rated current;
- rated maximum breaking current;
- class (Back-Up, General-Purpose, Full-Range);
- rated minimum breaking current (for Back-Up fuses only);
- maximum application temperature (for fuse-links designed for use in surrounding temperatures above 40 °C tested in accordance with Annex E);
- type of striker (light, medium or heavy), if any;
- location of the striker (if applicable);
- identifying date code (minimum of month and year).

It shall also be indicated on both fuse-link and fuse-base, when applicable, if they are designed for outdoor service, or for use in insulating liquid, unless this information is included in the type designation or identification code.

6.3 Dimensions

While this document contains no normative requirements for overall fuse dimensions, informative Annex D contains a collection and classification of types and dimensions specified in the various existing national standards.

7 Type tests performed on all fuses**7.1 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. 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 design is modified in a way which might modify the performance.

Tests made on fuse-links fitted with strikers or indicators are valid for fuse-links otherwise identical but without strikers or indicators.

For convenience of testing, and with the previous consent of the manufacturer, the values prescribed for the tests, particularly the tolerances, can be changed so as to make the test conditions more severe. Where a tolerance is not specified, type tests shall be carried out at values no less severe than the specified values, the upper limits being subject to the consent of the manufacturer.

Tests specified in this document 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.

7.2 List of type tests

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

- dielectric tests (fuse-base only) (7.4);
- temperature-rise tests and power-dissipation measurement (7.5);
- breaking tests (7.6);
- tests for time-current characteristics (7.7).

7.3 Common test practices for all type tests

7.3.1 General

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

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

7.3.2 Mounting of fuse-link

The fuse-link shall be tested on a fuse-base as specified by the manufacturer of the fuse-link, unless the fuse-link is not intended to be installed in a fuse-base, in which case the manufacturer's mounting instructions shall be followed.

7.3.3 Condition of device to be tested

The device shall be new, clean and in good condition. Before the tests are made, with the exception of dielectric 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.

7.3.4 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.

Fuses used in a fuse enclosure package (FEP) shall be mounted in accordance with the FEP or fuse manufacturer's specifications. The enclosure and base of the device shall be earthed, if applicable.

Earthing is not required for temperature rise tests (7.5) and time-current tests (7.7).

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

7.4 Dielectric tests

7.4.1 Test practices

7.4.1.1 General

Dielectric test practices shall be as specified in 7.3 and as follows.

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

7.4.1.2 Mounting

For multipole 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.

7.4.1.3 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.

7.4.2 Application of test voltage for impulse and power-frequency test

The test voltage specified in Table 4 and Table 5 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 ready for service;
- 2) with the fuse-link removed.

For multi-pole arrangements of fuses test:

- between all live parts of all poles connected together and the earthable metal parts;
- 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.

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.

7.4.3 Atmospheric conditions during test

The test shall be made at atmospheric conditions as near as possible to the standard conditions specified in 4.3.1 of IEC 60060-1:2010.

The correction factors for air density and for air humidity, as given in 4.3 of IEC 60060-1:2010, may be used for fuses pending further information.

7.4.4 Lightning impulse voltage dry tests

Fuses shall be subjected to lightning impulse voltage dry tests with 1,2/50 impulses in accordance with Clause 7 of IEC 60060-1:2010.

Fifteen consecutive impulses at the rated lightning impulse withstand voltages specified in Table 4 and Table 5 shall be applied as follows:

- at the rated withstand voltage to earth and between poles for all the test conditions specified in a) of 7.4.2;
- at the rated withstand voltage to earth and between poles for the test condition b) of 7.4.2 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 7.4.2 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 in accordance with IEC 60071-1.

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 breakdown voltage, it shall suffice to test with that polarity only.

7.4.5 Power-frequency voltage dry tests

Fuses shall be subjected to 1 min, power-frequency voltage dry tests as specified in IEC 60060-1.

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 1 min, power-frequency withstand voltage tests are specified in Table 4 and Table 5. The tests shall be made at the following values:

- at the rated withstand voltage to earth and between poles for all the test conditions specified in a) of 7.4.2;
- at the rated withstand voltage to earth and between poles for the test conditions b) of 7.4.2 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 7.4.2 if isolating properties are assigned to the fuse-base.

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

7.4.6 Power-frequency wet tests

Outdoor type fuses shall be subjected to power-frequency voltage wet tests under the same conditions as specified in 7.4.5. However, if a disruptive discharge on self-restoring external 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 4.4 of IEC 60060-1:2010.

7.5 Temperature-rise tests and power-dissipation measurement

7.5.1 Test practices

7.5.1.1 General

Temperature-rise tests and power-dissipation measurement shall be made as specified in 7.3 on one fuse and as follows.

7.5.1.2 Test sample

The fuse-link shall be of the highest current-rating in each body size and configuration for use in a fuse-base or mounting means specified by the fuse manufacturer.

7.5.1.3 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 vertically, unless another orientation is specified by the manufacturer, and connected to the test circuit by bare copper conductors as follows: each conductor shall be approximately 1 m 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 10.

Table 10 – Electrical connection to the test circuit – Conductor sizes

Current rating of the fuse-link ^a A	Size of bare copper conductors ^b 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
^a For fuse-links in parallel, the current rating to be considered is the total current assigned by the manufacturer. ^b The equivalent area in MCM (thousands of circular mils) can be obtained by multiplying the numbers in mm ² by two.	

Liquid-tight fuse-links shall be tested in a liquid-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 liquid 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 10. The insulating liquid to be used shall be one approved by the fuse manufacturer.

Normal clearances need not be provided.

Tests shall be made with the rated current of the fuse-link and at a frequency of 62 Hz or lower (including DC). 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/h).

The temperature rise of the various parts of the fuse shall not exceed the values specified in 5.2.7.

A thermally operated striker, if fitted, shall not deploy during the test.

7.5.2 Measurement of temperature

7.5.2.1 Temperature of fuse parts

The temperature of the various parts for which limits are specified shall be determined by devices such as thermocouples 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 below, close to the device (that is, in the liquid that cools the device).

7.5.2.2 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 taking the reading from a thermocouple (or thermometer) placed between 30 cm and 1 m from the side of the device. 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 in 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.

7.5.3 Measurement of power dissipation

Measurement of the power dissipation (of a fuse-link) shall 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. Measurement shall be made when the voltage drop (the temperature) has reached a steady-state value for the current value considered. The power dissipation is expressed in watts. For a high-voltage fuse, the product of voltage drop and current is considered a sufficient approximation to the power dissipation of a fuse-link.

NOTE Switchgear manufacturers and users who incorporate fuses into their equipment can 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.

7.6 Breaking tests

7.6.1 Test practices

7.6.1.1 General

Breaking test practices shall be as specified in 7.3 and as follows.

7.6.1.2 Description of tests to be made

Tests shall be made according to the instructions given in Table 11 and shall include at least 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 .

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 Note 1 below).

NOTE 1 The appropriate current, I_2 , to meet the requirements of Test Duty 2 specified in Table 11 is based on the design of the fuse-link. If the current has not been determined, based on previous experience or analysis, one or more of the following methods provides an estimate of the value of the current I_2 needed to comply with the requirements. The accuracy of each method (i.e. how close the calculated current is to a prospective current that actually meets the requirements of Table 11) will depend on the fuse-link design.

- 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:

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

where

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) The estimated I_2 is a current value between three and four times the current which corresponds to a pre-arcing time of one half-cycle on the time-current characteristic (see 7.7 and 5.2.9).
- c) If a time-current characteristic curve exists for virtual times less than 0,010 s, the estimated I_2 equals a value corresponding to the current at a time of 0,08 normal half-cycle on this time-current characteristic curve.

Test Duty 3: Verification of operation at current I_3 :

- 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 1 h or more;
- for Full-Range fuses, I_3 is equal to the rated current of the fuse-link. This is in order to allow for the possibility of severe derating which would bring the value of minimum melting current down to near to the fuse rated current.

Test I_t : for fuse-links that exhibit crossover current(s) (see 7.6.1.2).

In the case of fuses that incorporate different arc-quenching mechanisms within the same physical envelope (for example, current-limiting elements and expulsion elements in series), Test Duties 1, 2 and 3 above shall 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 breaking mechanism to another. Since fuse designs differ widely, specifying precise test requirements, applicable to all designs, is not possible. It is the responsibility of the fuse manufacturer to confirm by the I_t breaking test that the breaking mechanisms are operating correctly to effect proper current interruption within the transitional current region. Typical criteria used by the manufacturer in assessing compliance with this requirement are discussed in Annex F.

Additional breaking test requirements for fuse-links intended for use at surrounding temperatures above 40 °C are covered in Annex E.

Values of I_1 , I_2 , I_3 and I_t are the RMS values of the AC component of the current.

If, in carrying out the 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.

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 electrical degrees between each. (The parameters used will be those of Test Duty 2 (see Table 11) except for the making angle and value of instantaneous current at initiation of arcing.)

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

It is not necessary to make breaking tests on fuse-links of all current ratings of a homogeneous series; see 7.6.4 for the requirements to be met and tests to be made.

A homogeneous series of Back-Up fuse-links can also 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 7.6.5 for the requirements to be met.

NOTE 2 Series I voltages are based on system insulation voltages and Series II voltages are based on system insulation voltages and certain operational requirements (including additional voltages). To be suitable, therefore, for some applications that use Series II voltages (generally North American style systems), Test Duty 1 and Test Duty 2 tests using Series II voltages are performed at the fuse rated voltage (Table 11, footnote b).

7.6.1.3 Test I_t (for fuse-links that exhibit cross-over current)

In general, a minimum of two tests shall be performed at each of the two following values:

$$I_{t1} = 1,2 I_t (\pm 0,05 I_t)$$

and

$$I_{t2} = 0,8 I_t (\pm 0,05 I_t)$$

where I_t is the value of crossover current provided by the fuse manufacturer.

If it is known that these values do not represent the most onerous conditions for the given design of fuse, then the manufacturer may nominate other values of I_{t1} and I_{t2} .

The parameters to be used when performing the tests, depending on the values of the cross-over current I_t , are as follows:

- I_t in the short-circuit (current-limiting) range: all test conditions as given in Table 11 as appropriate for the test current;
- I_t in the low over-current range, i.e. below 12 times rated current: power factor and power frequency recovery voltage as specified for Test Duty 3;
- I_t in the intermediate current range:
 - Power frequency recovery voltage: rated voltage $^{+5}_0$ %;
 - Power factor:
 - 0,3 to 0,4 lagging if the cross-over current I_t is between 12 and 25 times rated current I_r ;
 - 0,2 to 0,3 lagging if the cross-over current I_t is between 25 times rated current I_r and I_2 ;
 - TRV: Specified by the fuse-link manufacturer, so as to represent typical values found in circuits for which the fuse-link is intended as being suitable for use, based on the necessary test currents. Guidance as to appropriate values of TRV may be obtained from test standards for other switching devices intended for use under similar circumstances.

The tests should be performed in the current region where there is an abrupt or gradual cross-over of breaking duty from one breaking mechanism to another. Test current values are to be provided by the manufacturer. Typical criteria used by the manufacturer in assessing compliance with this requirement are discussed in Annex F.

Table 11 – Breaking tests – Parameters

Parameters	Test duties		
	1 ^a	2	3
Power-frequency recovery voltage	(0,87 × rated voltage) $+5\%$ -0% ^b		Rated voltage $+5\%$ -0%
Prospective TRV characteristics	See 6.6.1.4		Not specified
Power factor	From 0,07 to 0,15 ^c		0,4 to 0,6
Prospective current (RMS value of the AC component)	I_1 $+5\%$ -0%	I_2	I_3 0% -10% ^d
Instantaneous current at initiation of arcing	Not applicable	From 0,85 I_2 to 1,06 I_2	Not applicable
Making angle	Not before voltage zero	From 0° to 20° after voltage zero	Random timing ^e
Initiation of arcing after voltage zero	For one test: From 40° to 65° For two tests: From 65° to 90°	Not applicable	Not applicable
Maintained voltage after breaking	Not less than 15 s	Not less than 60 s or 5 min ^f	
Number of tests	3	3	2
^a Since the operating conditions can produce a wide variety of stresses on the fuse and, as the breaking tests are intended in principle to produce the most severe conditions mainly as regards the arc energy and the thermal and mechanical stresses for this value of current, it is recognised that these conditions will be practically obtained at least once, when making the three tests indicated. ^b Tests made using voltages from Series II (5.2.1) shall be performed at rated voltage (+5 %, –0 %). ^c When the manufacturer agrees, the lower limit does not apply. ^d When testing station limitations prevent the maintenance of constant current, the tolerance on the current can be exceeded in either direction during not more than 20 % of the total melting time, provided that the current at the initiation of arcing is within the tolerance specified for Test Duty 3. ^e The making angle may be random providing that the melting time of the fuse is greater than 0,1 s. If the melting time is 0,1 s or less, a making angle of arccos (power factor) ± 10° shall be used (to give an approximately symmetrical current). A circuit power factor lower than 0,4 shall not be used for this test. ^f For an organic fuse-link, the maintained voltage period after breaking shall be not less than 5 min for the following specific cases: Test Duty 2: for Back-Up, General-Purpose, and Full-Range types Test Duty 3: for General-Purpose and Full-Range types These longer periods of maintained voltage apply only to the largest current rating of a homogeneous series, and do not apply where such fuses are intended only for use in striker-tripped switch-fuse combinations.			

7.6.1.4 General characteristics of the test circuit

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

Where test station limitations make it difficult for the full value of recovery voltage to be maintained for the specified duration, the test circuit may be switched to an auxiliary source. Such changeover shall not be made until a time of at least 10 s has elapsed from current interruption. Any necessary circuit interruption to effect the changeover shall not exceed 0,2 s duration. The auxiliary source shall be capable of supplying a current of at least 1 A, while maintaining the specified recovery voltage for the remainder of the specified duration. Any breakdown of the fuse during the voltage-holding period (i.e. an increase in leakage current through the fuse to 1 A or more) shall be considered an unsuccessful fuse interruption. Current monitoring may be by any convenient method. One acceptable method is to trip a circuit breaker used to protect the auxiliary source.

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 7 and Figure 8. No reactors shall be used that are vulnerable to saturation.

The test-circuit frequency shall be between 48 Hz and 62 Hz.

It is recommended that there be no distortion of the power-frequency recovery voltage that can readily be seen by inspection of the oscillogram. The test circuit waveshape shall meet the requirements of a sinusoidal voltage as specified in IEC 60060-1.

A measuring system with appropriate frequency response shall be provided for switching voltage measurement during Test Duties 1, 2 and I_t . For Test Duty 3, this measuring system may be replaced by a sphere-gap or a device of equivalent response.

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

7.6.1.5 Transient recovery voltage (TRV)

7.6.1.5.1 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 document, the transient recovery voltage approximates to a damped single-frequency oscillation. This waveform is adequately described by an envelope (reference line) consisting of two line segments defined by means of two parameters (see Annex A).

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 (t_d) and a delay line.

The following parameters are used for the representation of the TRV (see Figure 4):

- a) u_c : TRV peak voltage in kilovolts;
- b) t_3 : time in microseconds to voltage u_c .

This gives reference line OAC in Figure 4.

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').

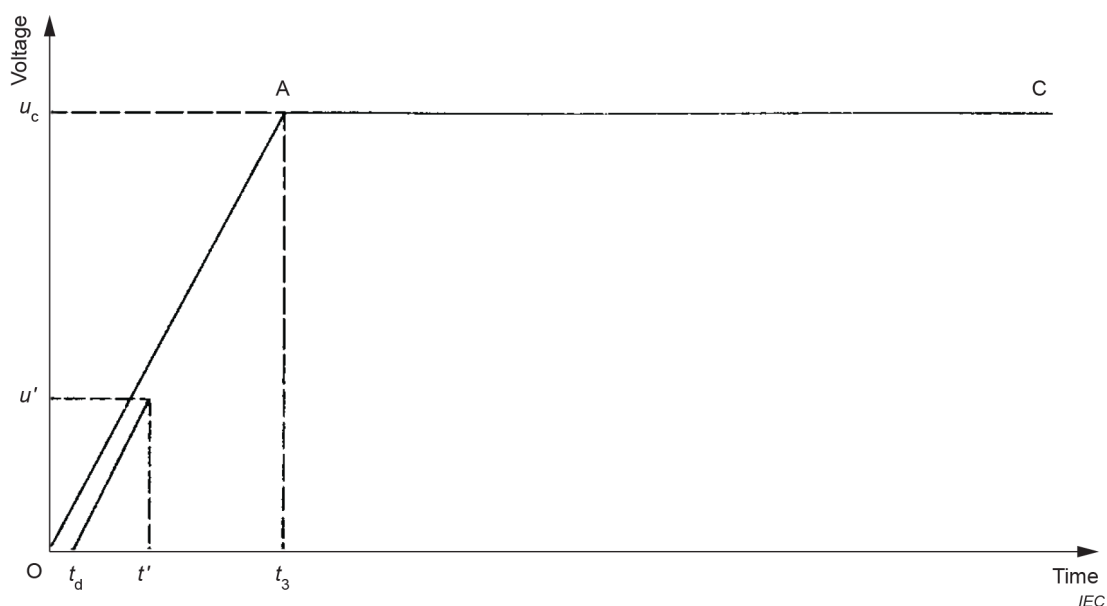


Figure 4 – Representation of a specified TRV by a two-parameter reference line and a delay line

7.6.1.5.2 General TRV requirements

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.

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 7.1).

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

These requirements are illustrated in Figure 5.

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

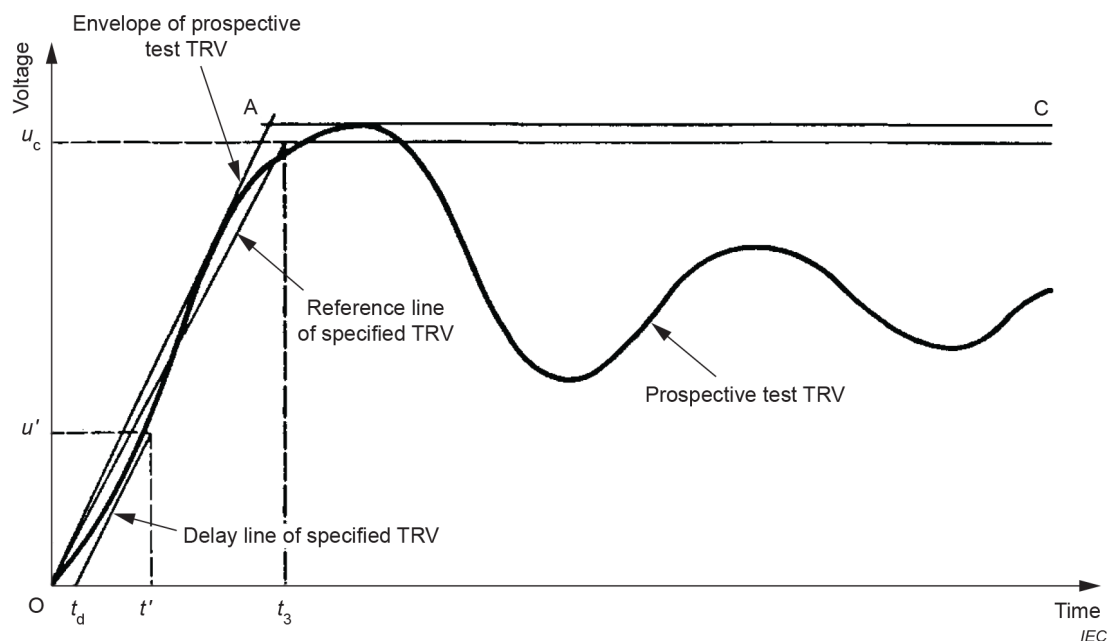


Figure 5 – Example of a two-parameter reference line for a TRV complying with the conditions of the type test

7.6.1.5.3 TRV for Test Duty 1

In principle, the tests are made with the standardised values of TRV specified in 7.6.1.5.1 and Table 12 or Table 13. 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 electrical degrees 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 Table 12 or Table 13 and an initial portion not crossing the specified delay line. All the tests of Test Duty 1 shall be made in this new circuit.

Table 12 – Standard values of rated TRV for I_1 – Series I rated voltages

Rated voltage	Basic parameters		Derived values			
	Peak voltage ^a	Time coordinate	Time delay ^b	Voltage coordinate ^c	Time coordinate ^d	Rate of rise
U_r	u_c	t_3	t_d	u'	t'	u_c/t_3
kV	kV	μs	μs	kV	μs	kV/μs
3,6	6,2	40	6	2,06	19,4	0,154
7,2	12,4	52	7,8	4,1	25	0,238
12	20,6	60	9	6,9	29	0,345
17,5	30	72	10,8	10	35	0,415
24	41	88	13,2	13,8	42,5	0,47
36	62	108	16,2	20,6	52	0,57
40,5	69	115	17,2	23	55,5	0,60
52	89	132	19,8	29,5	63,8	0,68
72,5	124	168	8,4	41,5	64,4	0,74

^a $u_c = 1,5 \times 1,4 \sqrt{\frac{2}{3}} U_r$ (using a first-pole-to-clear value of 1,5 and an amplitude factor of 1,4)

^b $t_d = 0,15 t_3$ for $U_r \leq 52$ kV and $t_d = 0,05 t_3$ for $U_r > 52$ kV

^c $u' = 1/3 u_c$

^d $t' = (0,15 + 1/3) t_3$ for $U_r \leq 52$ kV and $t' = (0,05 + 1/3) t_3$ for $U_r > 52$ kV

Table 13 – Standard values of rated TRV for I_1 – Series II rated voltages

Rated voltage	Basic parameters		Derived values			
	Peak voltage ^a	Time coordinate	Time delay ^b	Voltage coordinate ^c	Time coordinate ^d	Rate of rise
U_r	u_c	t_3	t_d	u'	t'	u_c/t_3
kV	kV	μs	μs	kV	μs	kV/μs
2,8	5,5	39	5,9	1,8	18,9	0,141
5,5	10,9	46	6,9	3,6	22,2	0,237
8,3	16,4	54	8,1	5,5	26,1	0,304
15,5	30,7	67	10,0	10,2	32,2	0,458
17,2	34,1	70	10,5	11,4	33,8	0,487
23,0	45,5	84	12,6	15,2	40,6	0,542
27,0	53,5	93	14,0	17,8	45,0	0,575
38,0	75,2	111	16,6	25,1	53,6	0,677
48,3	95,6	125	18,8	31,9	60,4	0,765
72,5	143,5	165	8,3	47,8	63,3	0,870

^a $u_c = 1,0 \times 1,4 \times \sqrt{2} U_r$ (using line-to-line voltage and an amplitude factor of 1,4 – see Table 11 footnote b)

^b $t_d = 0,15 t_3$ for $U_r \leq 48,3$ kV and $t_d = 0,05 t_3$ for $U_r > 48,3$ kV

^c $u' = 1/3 u_c$

^d $t' = (0,15 + 1/3) t_3$ for $U_r \leq 48,3$ kV and $t' = (0,05 + 1/3) t_3$ for $U_r > 48,3$ kV

The values given in the tables are prospective values and take into account depression of recovery voltage.

In the case of single-phase systems using fuses tested to Series I voltages, or where fuses are for use in an installation having more severe conditions, the values shall be subject to agreement between manufacturer and user.

7.6.1.5.4 TRV for Test Duty 2

Tests shall be made with the values of prospective TRV specified in Table 14 or Table 15 (see Annex B).

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

- its highest peak shall be not smaller than the parameter u_c specified;
- 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).

Especially for fuses where the test current I_2 is small, it may be difficult to achieve the values of time coordinate specified. In such cases, and subject to agreement by the manufacturer, greater values of t_3 are acceptable and should be stated in the test report.

Table 14 – TRV for Test Duty 2 – Series I rated voltages

Rated voltage	Basic parameters		Rate of rise
	Peak voltage	Time coordinate	
U_r	u_c^a	t_3	u_c/t_3
kV	kV	μs	kV/ μs
3,6	6,6	120 to 160	0,055 to 0,041
7,2	13,2	156 to 208	0,084 to 0,063
12	22	180 to 240	0,122 to 0,091
17,5	32	216 to 288	0,148 to 0,111
24	44	264 to 352	0,167 to 0,125
36	66	324 to 432	0,203 to 0,152
40,5	74	345 to 460	0,214 to 0,160
52	96	396 to 528	0,242 to 0,181
72,5	133	504 to 672	0,265 to 0,199
^a $u_c = 1,5 \times 1,5 \times \sqrt{\frac{2}{3}} U_r$ (first-pole-to-clear factor of 1,5 and amplitude factor of 1,5)			

Table 15 – TRV for Test Duty 2 – Series II rated voltages

Rated voltage	Basic parameters		Rate of rise
	Peak voltage	Time coordinate	
U_r	u_c^a	t_3	u_c/t_3
kV	kV	μs	kV/ μs
2,8	5,9	111 to 148	0,053 to 0,040
5,5	11,7	138 to 184	0,085 to 0,064
8,3	17,6	162 to 216	0,109 to 0,081
15,5	32,9	201 to 268	0,164 to 0,123
17,2	36,5	210 to 280	0,174 to 0,130
23	48,8	252 to 336	0,194 to 0,145
27	57,3	279 to 372	0,205 to 0,154
38	80,6	333 to 444	0,242 to 0,182
48,3	102,5	381 to 508	0,269 to 0,202
72,5	153,8	504 to 672	0,305 to 0,229

^a $u_c = 1,0 \times 1,5 \times \sqrt{2} U_r$ (using a line-to-line voltage and an amplitude factor of 1,5 – see Table 11 footnote b)

7.6.1.5.5 TRV for Test Duty 3

TRV characteristics are not specified; the reactance of the circuit (which may be the reactance of the transformer or the reactance of the transformer and reactor(s)) shall be shunted by a resistance R_p with a value equal to approximately 40 times the value of the reactance. However, if this value does not result in at least critical damping, the resistance shall be lower to achieve critical damping (see Annex B).

Critical damping is obtained when

$$R = \frac{1}{2} \frac{f_0}{f_N} X$$

where

f_0 is the natural frequency of the circuit without additional damping;

f_N is the power frequency;

X is the reactance of the circuit at power frequency.

7.6.1.6 Arrangement of the equipment

7.6.1.6.1 Fuses intended for use in air

For Test Duties 1 and 2, the conductors shall be arranged as shown in Figure 6, in order to reproduce the electromagnetic forces that may occur in service. To prevent any movement of the conductors from causing excessive mechanical stresses on the fuse-base, the conductors shall be secured at a distance equal to the insulator height if this height exceeds 0,50 m (20 in), or at 0,50 m (20 in) if the insulator height does not exceed 0,50 m (20 in). The bends shall be placed immediately after the bracing points. No arrangements are specified for Test Duty 3. The fuse shall be tested in the vertical orientation unless it is known that the horizontal arrangement is more severe, in which case the fuse shall be tested horizontally. If a fuse-link is not usually mounted in a fuse base, the mounting and orientation shall be as specified by the manufacturer.

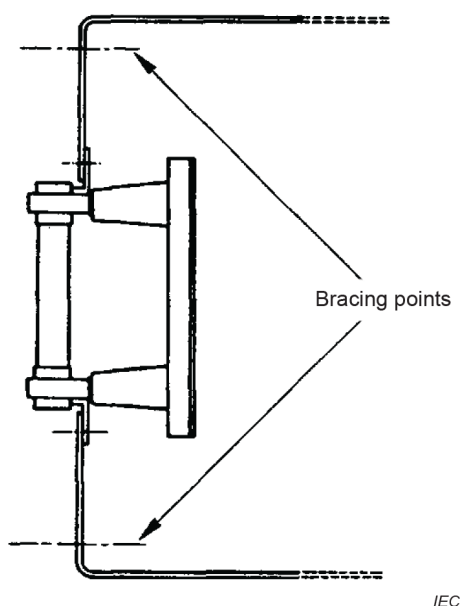


Figure 6 – Breaking tests – Arrangement of the equipment

7.6.1.6.2 Fuses intended for use in liquid-filled enclosures

Test Duties 1, 2, 3, and I_t may be performed in air or in a liquid-filled enclosure. Since testing in air is held to be more onerous, this may only be done with the agreement of the fuse manufacturer, and in the case of failure, the relevant test duty may be repeated with the fuse in a liquid-filled enclosure, using an arrangement of test conductors suitable for that enclosure. The liquid-filled enclosure may be the same as used for the temperature rise tests, suitably reinforced, where necessary, with the fuse-link moved to equalise dielectric clearance to the tank and utilising suitable fuse contacts.

7.6.2 Test procedure

7.6.2.1 Calibration of the test circuit

The fuse or the fuse-link under test shall be replaced by a link of negligible impedance as shown in Figure 7 and Figure 8.

The circuit shall be adjusted to give the specified prospective current. This shall be verified by an oscillographic or similar record.

For direct tests of Test Duty 3, the calibration of the test circuit may not be necessary, but when made, current may be measured by an ammeter as an alternative to an oscillographic record.

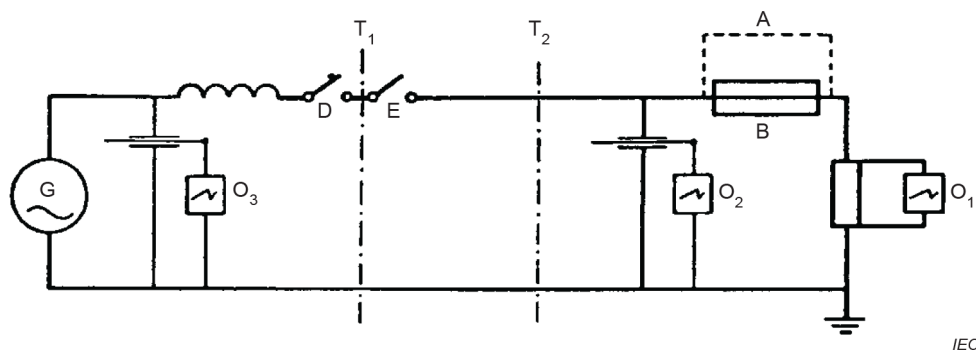
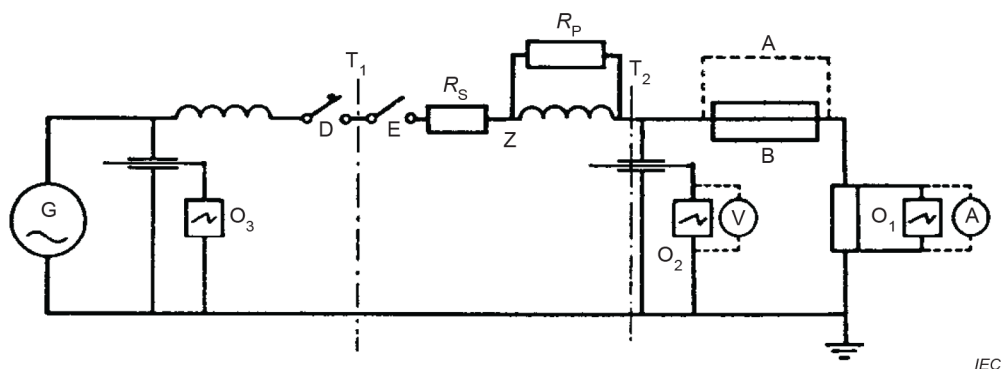


Figure 7 – Breaking tests – Typical circuit diagram for Test Duties 1 and 2



Key for Figures 7 and 8

A	Removable link used for the calibration test	O ₃	Reference voltage measurement
B	Fuse under test	T ₁ and T ₂	Possible locations of the transformer
D	Circuit-breaker protecting the source	Z	Adjustable impedance
E	Making switch	R _p	Adjustable parallel resistance
O ₁	Current measurement	R _s	Adjustable series resistance
O ₂	Recovery voltage measurement		

Figure 8 – Breaking tests – Typical circuit diagram for Test Duty 3

7.6.2.2 Test method

The link A is removed and is replaced by the fuse or the fuse-link B under test.

The making switch E is closed at such an instant as to provide the conditions specified in Table 11.

For Test Duties 1, 2, 3 and I_t , switching voltages shall be measured. For Test Duties 1 and 2, cut-off currents shall be determined.

In Test Duty 3, an ammeter shall not be used except for measuring the current during long pre-arcing time tests. An oscillograph or similar measuring system shall be used to measure current immediately before interruption occurs.

After the fuse has operated, recovery voltage shall be maintained across the fuse for the period specified in Table 11. The first few cycles shall be recorded by an oscillograph or similar system and the remainder may be observed on a voltmeter.

During this period, the power frequency may fall below the specified minimum value.

7.6.2.3 Interpretation of oscillograms

For Test Duties 1 and 2, the prospective breaking current shall be the RMS value of the AC component of the current, measured one half-cycle after the initiation of short circuit in the calibration test (see Figure 9 and Figure 10).

For Test Duty 3 and I_t tests, the breaking current shall be the RMS symmetrical current measured at the instant of the initiation of the arc in the breaking test (see Figure 11).

The value of the power-frequency recovery voltage is measured between the peak of the second non-influenced half-wave and the straight line drawn between the peaks of the preceding and following half-waves (see Figure 9, Figure 10, and Figure 11).

7.6.2.4 Parameters to be used for tests

The parameters to be used when making the tests are given in Table 11.

If a test is made under more severe conditions than specified and if this test is successful, this test shall be valid.

7.6.3 Alternative test methods for Test Duty 3

7.6.3.1 General

Test Duty 3 may be performed using a single high-voltage source throughout the test (as in Test Duty 1 or Test Duty 2).

However, where pre-arcing times are long and/or where there are limitations in test-station capability, the Test Duty 3 tests may be conducted as a two-part test. For the first part of the test duration, current is supplied from a low-voltage source. For the second part, which includes the interruption of the current by the fuse, current is supplied from a high-voltage source.

It is also permissible to perform a two-part test using a single high-voltage source where the power factor for part of the pre-arcing period is of a lower value. In this case, the changeover to the correct power factor shall occur before arcing commences.