

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

Withdrawn



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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.

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The text of this standard is based on the following documents:

FDIS	Report on voting
32A/274/FDIS	32A/277/RVD

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

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

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

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

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- withdrawn,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

Withdrawn

HIGH-VOLTAGE FUSES –

Part 1: Current-limiting fuses

1 General

1.1 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.

Some fuses are provided with fuse-links equipped with an indicating device or a striker. These fuses come within the scope of this standard, but the correct operation of the striker in combination with the tripping mechanism of the switching device is outside the scope of this standard; see IEC 62271-105.

1.2 Normative references

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

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60265-1:1998, *High-voltage switches – Part 1: Switches for rated voltages above 1 kV and less than 52 kV*

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

IEC 60644:1979, *Specification for high-voltage fuse-links for motor circuit applications*

IEC/TR 60787:2007, *Application guide for the selection of high-voltage current-limiting fuse-links for transformer circuits*

IEC 62271-105:2002, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations*

ISO 148-2, *Metallic materials – Charpy pendulum impact test – Part 2: Verification of test machines*

ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*

2 Normal and special service conditions

2.1 Normal service conditions

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

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

The minimum ambient air temperature is –25 °C.

NOTE 1 The time-current characteristics of fuses will be modified at the minimum and maximum temperatures.

- b) The altitude does not exceed 1 000 m.

NOTE 2 The rated voltages and insulation levels specified in this standard apply to fuses intended for use at altitudes not exceeding 1 000 m. When fuses incorporating external insulation are required for use at altitudes above 1 000 m, one or other of the following procedures should be adopted.

- a) The test voltages for insulating parts in air should be determined by multiplying the standard test voltages given in Tables 4 and 5 by the appropriate correction factor given in column (2) of Table 1.
- b) The fuses may be selected with a rated voltage which, when multiplied by the appropriate correction factor given in column (3) of Table 1 is not lower than the highest voltage of the system.

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

Table 1 – Altitude correction factors – Test voltage and rated voltage

Maximum altitude m (1)	Correction factor for test voltages referred to sea-level (2)	Correction factor for rated voltages (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.

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

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

Table 2 – Altitude correction factors – Rated current and temperature rise

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

- c) The ambient air is not excessively (or abnormally) polluted by dust, smoke, corrosive or flammable gases, vapour or salt.
- d) For indoor installations, the conditions of humidity are under consideration but, in the meantime, the following figures can be used as a guidance:
- 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.

For these conditions, condensation may occasionally occur.

NOTE 4 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 5 To withstand the effects of high humidity and occasional condensation, such as breakdown of insulation or corrosion of metallic parts, indoor fuses designed for such conditions and tested accordingly or outdoor fuses may be used.

NOTE 6 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment.

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

In addition, for outdoor installations,

- f) account should be taken of the presence of condensation or rain and rapid temperature changes;
- g) the wind pressure does not exceed 700 Pa (corresponding to 34 m/s wind speed);
- h) the solar radiation does not exceed 1,1 kW/m².

2.2 Other service conditions

Fuse-links intended for use at surrounding temperatures (see 3.3.11) above 40 °C are covered in this standard in Annex E.

2.3 Special service conditions

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

2.4 Environmental behaviour

Fuses complying with this standard are inert devices during normal service. It is also a requirement of 5.1.3 that no significant external emission takes place. Therefore, they are regarded as environmentally safe devices in service and operation.

3 Terms and definitions

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

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 Examples of rated values usually stated for fuses, voltage, current and breaking current.

[IEV 441-18-35 modified]

3.1.2

rating

set of rated values and operating conditions

[IEV 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 For the method to evaluate and to express the prospective current, see 6.6.2.1 and 6.6.2.2.

[IEV 441-17-01, modified]

3.1.4

prospective peak current

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

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

[IEV 441-17-02]

3.1.5

prospective breaking current

prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process

NOTE For the fuses, this instant is usually defined as the moment of the initiation of the arc during the breaking process. Conventions relating to the instant of the initiation of the arc are given in 6.6.2.3.

[IEV 441-17-06]

3.1.6

breaking capacity

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

[IEV 441-17-08, modified]

3.1.7

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

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

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

[IEV 441-17-12, modified]

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

[IEV 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

[IEV 441-17-37, modified]

3.1.10

operating time

total clearing time

sum of the pre-arcing time and the arcing time

[IEV 441-18-22]

3.1.11

Joule integral

I^2t

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

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

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

[IEV 441-18-23 modified]

3.1.12

virtual time

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

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

[IEV 441-18-37 modified]

3.1.13

time-current characteristic

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

[IEV 441-17-13]

3.1.14

cut-off (current) characteristic

let-through (current) characteristic

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

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

[IEV 441-17-14]

3.1.15

recovery voltage

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

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

[IEV 441-17-25, modified]

3.1.16 **transient recovery voltage** **TRV**

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

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

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

[IEV 441-17-26, modified]

3.1.17 **power-frequency recovery voltage**

recovery voltage after the transient voltage phenomena have subsided

[IEV 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 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.

[IEV 441-17-29, modified]

3.1.19 **switching voltage**

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

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

[IEV 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

[IEV 441-18-29]

3.1.21 **power dissipation** (in a fuse-link)

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

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

[IEV 441-18-38]

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 in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device

[IEV 441-18-01]

3.2.2

terminal

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

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

3.2.3

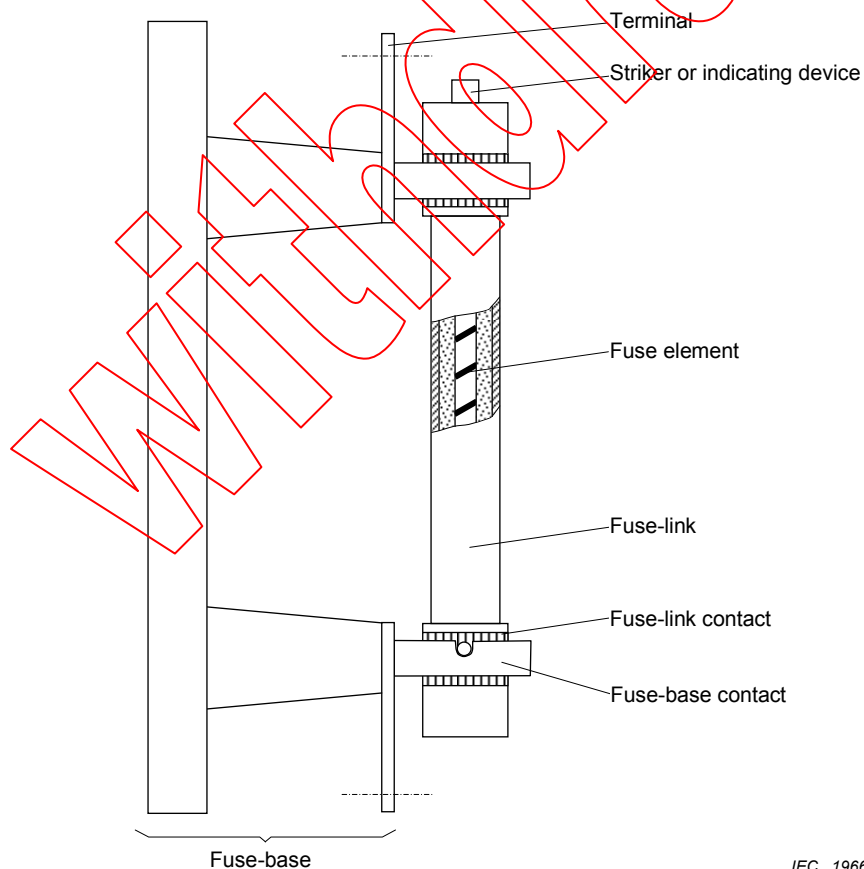
fuse-base

fuse-mount

fixed part of a fuse provided with contacts and terminals

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

[IEV 441-18-02]



IEC 1966/05

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)

[IEV 441-18-03, modified]

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](#))

[IEV 441-18-09]

3.2.6

fuse-link contact

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

[IEV 441-18-04, modified]

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](#))

[IEV 441-18-08]

3.2.8

indicating device indicator

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

[IEV 441-18-17]

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

[IEV 441-18-18]

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

[IEV 441-18-10, modified]

3.3.2

classes

three classes of current-limiting fuses are defined according to the range in which they can be used:

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

See 9.3.3.

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 the current that causes melting of the fuse element in 1 h or more

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 6.6.1.1, 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

[IEV 411-18-06, modified]

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 6.6.4.1)

[IEV 441-18-34]

3.3.8

external insulation

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

[IEV 604-03-02, modified]

3.3.9

self-restoring insulation

insulation which completely recovers its insulating properties after a disruptive discharge

[IEV 604-03-04]

3.3.10

organic fuse-link

a 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. 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

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

4 Ratings and characteristics

4.1 General

- a) Ratings of the fuse-base
 - 1) Rated voltage (4.2)
 - 2) Rated current (4.5)
 - 3) Rated insulation level (power-frequency, dry, wet and impulse withstand voltages) (4.3)
- b) Ratings of the fuse-link
 - 1) Rated voltage (4.2)
 - 2) Rated current (4.6)
 - 3) Rated maximum breaking current (4.8.1)
 - 4) Rated frequency (4.4)
 - 5) Rated minimum breaking current for Back-Up fuses and class (4.8.2)
 - 6) Rated TRV (4.10)
- c) Characteristics of the fuse
 - 1) Temperature rise limits (4.7)
- d) Characteristics of the fuse-link
 - 1) Class (3.3.2 and 4.8.2)
 - 2) Switching voltages (4.9)
 - 3) Time-current characteristics (4.11)
 - 4) Cut-off characteristics (4.12)
 - 5) I^2t characteristics (4.13)
 - 6) Mechanical characteristics of the strikers (4.14)
 - 7) Maximum application temperature (see Annex E).

4.2 Rated voltage

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

NOTE This rated voltage is equal to the highest voltage for the equipment (see Clause 8).

The rated voltage of a fuse should be selected from the voltages given in [Table 3](#).

Table 3 – Rated voltages

Series I kV	Series II kV
3,6	2,75
7,2	5,5
12	8,25
17,5	15
24	15,5
36	25,8
40,5	38
52	48,3
72,5	72,5

4.3 Rated insulation level (of a fuse-base)

The voltage values (both power frequency and impulse) that characterise the insulation of the fuse-base with regard to its capability of withstanding dielectric stresses (see Clause 8).

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 9.3.5).

The rated insulation level of a fuse-base should be selected from Tables 4 and 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 U.S.A. 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 kV (peak)		List 2 kV (peak)		(dry and wet) kV (r.m.s.)	
	To earth and between poles	Across the isolating distance of the fuse-base (see note)	To earth and between poles	Across the isolating distance of the fuse-base (see note)	To earth and between poles	Across the isolating distance of the fuse-base (see note)
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

NOTE 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) kV (peak)				Rated power-frequency withstand voltage kV (r.m.s.)					
	To earth and between poles		Across the isolating distance of the fuse-base (see note)		To earth and between poles		Across the isolating distance of the fuse-base (see note)			
	Indoor	Outdoor	Indoor	Outdoor	Indoor 1 min dry	Outdoor		Indoor 1 min dry	Outdoor	
						1 min dry	10 s wet		1 min dry	10 s wet
2,75	45	–	50	–	15	–	–	17	–	–
4,76	60	–	70	–	19	–	–	21	–	–
8,25	75	95	80	105	26	35	30	29	39	33
15	95	–	105	–	36	–	–	40	–	–
15,5	110	110	125	125	50	50	45	55	55	50
25,8	125	150	140	165	60	70	60	66	77	66
38	150	200	165	220	80	95	80	88	105	88
48,3	–	250	–	275	–	120	100	–	132	110
72,5	–	350	–	385	–	175	145	–	195	160

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

4.4 Rated frequency

Standard values of rated frequency are 50 Hz and 60 Hz.

4.5 Rated current of the fuse-base

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

The rated current of the 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.

4.6 Rated current of the fuse-link

The current assigned to the fuse-link that a new clean fuse-link will carry continuously without exceeding specified temperature rises when mounted on a fuse-base specified by the manufacturer and connected to the circuit with certain specified conductor sizes and lengths, at an ambient air temperature of not more than 40 °C (see Clause 8).

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.

4.7 Temperature-rise limits

The fuse-link and the fuse-base shall be able to carry their rated current continuously without exceeding the limits of temperature rise given in [Table 6](#) and without deterioration.

NOTE For fuses used in enclosures, see 6.5.3, 9.3.2 and Annex F.

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](#).

Withdrawn

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 coatings (footnote 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 coatings (footnote a)		
B Contacts in oil (copper or copper alloy):		
1 Spring-loaded contacts		
– bare	80	40
– silver-, tin- or nickel-coated	90	50
– other coatings (footnote a)		
2 Bolted contacts		
– bare	80	40
– silver-, tin- or nickel-coated	100	60
– other coatings (footnote a)		
C Bolted terminals in air:		
– bare	90	50
– silver-, nickel- or tin-coated	105	65
– other coatings (footnote a)		
D Metal parts acting as springs (footnote b)		
E Materials used as insulation and metal parts in contact with insulation of following classes (footnote c):		
Class Y (for non-impregnated materials)	90	50
Class A (for materials immersed in oil)	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 (footnote d)		
F Oil (footnotes e and f)		
	90	50
G Any part of metal or of insulating material in contact with oil 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 according to IEC 60085. ^d Limited only by the requirement not to cause any damage to surrounding parts. ^e At the upper part of the oil. ^f Special consideration should be given with regard to vaporisation and oxidation when low-flash-point oil is used.		

4.8 Rated breaking capacity

4.8.1 Rated maximum breaking current

The value of breaking capacity specified for a fuse.

The rated maximum breaking current in kA of the 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.

4.8.2 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.

4.9 Limits of switching voltage

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

On request, the manufacturer shall indicate the maximum value of the switching voltages as determined in the breaking tests (see 6.6).

Table 7 – Maximum permissible switching voltages

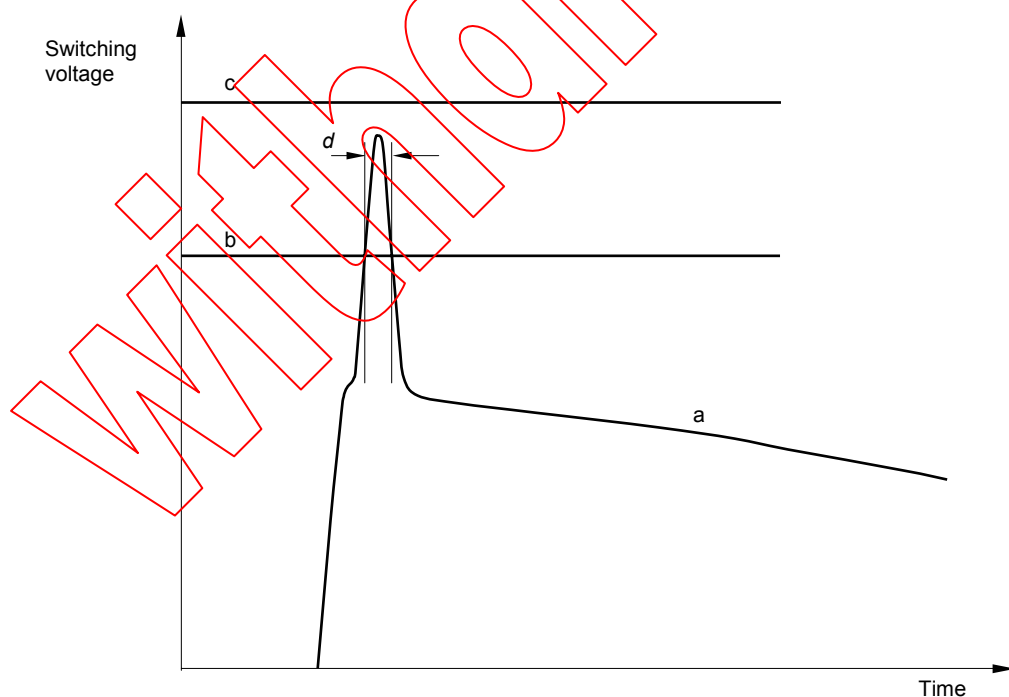
Series I		Series II	
Rated voltage kV	Maximum switching voltage kV	Rated voltage kV	Maximum switching voltage kV
3,6	12	2,75	8
7,2	23	5,5	18
12	38	8,25	26
17,5	55	15	47
24	75	15,5	49
36	112	22	70
40,5	126	25,8	81
52	162	27	84
72,5	226	38	119
		48,3	150
		72,5	226

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

Series I up to and including 3,2 A		Series II up to and including 12 A	
Rated voltage	Maximum switching voltage (footnotes a and b)	Rated voltage	Maximum switching voltage (footnote b)
kV	kV	kV	kV
36,6	26	2,75	13
7,2	36	5,5	25
12	50	8,25	38
17,5	63	15	68
24	85	15,5	70
3	120	22 to 25,8	117
		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 4.3).

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



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Key

- a Switching-voltage curve
b Switching-voltage limit – Table 7

- c Switching-voltage limit – Table 8
d $\leq 200 \mu$ s

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

4.10 Rated transient recovery voltage (rated TRV)

4.10.1 General

The rated transient recovery voltage related to the rated maximum breaking current (in accordance with 4.8) is the reference voltage which constitutes the upper limit of the prospective transient recovery voltage of circuits which the fuse shall be capable of breaking in the event of a short circuit.

Standard values of rated TRV are specified in Tables 9 and 10. These values apply to the rated maximum breaking current of a fuse.

Table 9 – Standard values of rated TRV – Series I

Rated voltage	Basic parameters		Derived values			
	Peak voltage	Time coordinate	Time delay (footnote a)	Voltage coordinate (footnote b)	Time coordinate (footnote c)	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	6,6	29,5	51	0,68
72,5	124	168	8,4	41,5	64	0,74
a $t_d = 0,15 t_3$ for $U_r < 52$ kV and $t_d = 0,05 t_3$ for $U_r \geq 52$ kV b $u' = 1/3 u_c$ with $u_c = 1,4 \times 1,5 \times \sqrt{2/3} U_r$ c $t' = (0,15 + 1/3) t_3$ for $U_r < 52$ kV and $t' = (0,05 + 1/3) t_3$ for $U_r \geq 52$ kV						

Table 10 – Standard values of rated TRV – Series II

Rated voltage	Basic parameters		Derived values			
	Peak voltage	Time coordinate	Time delay (footnote a)	Voltage coordinate (footnote b)	Time coordinate (footnote c)	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
2,75	4,7	37	5,5	1,6	18,1	0,127
5,5	9,4	46	6,9	3,1	22,2	0,204
8,25	14,4	54	8,1	4,8	26,1	0,266
15	25,7	66	9,9	8,6	32,0	0,390
15,5	26,6	67	10,0	8,8	32,2	0,400
25,8	44	91	13,6	14,7	44,0	0,48
38	65	111	16,6	21,7	53,6	0,58
48,3	83	127	19,0	27,6	61,2	0,65
72,5	124	168	8,4	41,5	64	0,74

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

b $u' = 1/3 u_c$ with $u_c = 1,4 \times 1,5 \times \sqrt{2/3} U_r$

c $t' = (0,15 + 1/3) t_3$ 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 or where fuses are for use in an installation having more severe conditions, the values shall be subject to agreement between manufacturer and user.

The rated transient recovery voltage corresponding to the rated maximum breaking current is used for testing at breaking currents equal to the rated value with the permitted deviation given in 6.6.1.2.2. For testing at breaking current less than the rated value, other values of transient recovery voltage are specified (see 6.6.1.2.3).

4.10.2 Representation of TRV

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

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

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

4.10.3 Representation of rated TRV

The following parameters are used for the representation of the rated TRV (see Figure 3):

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

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

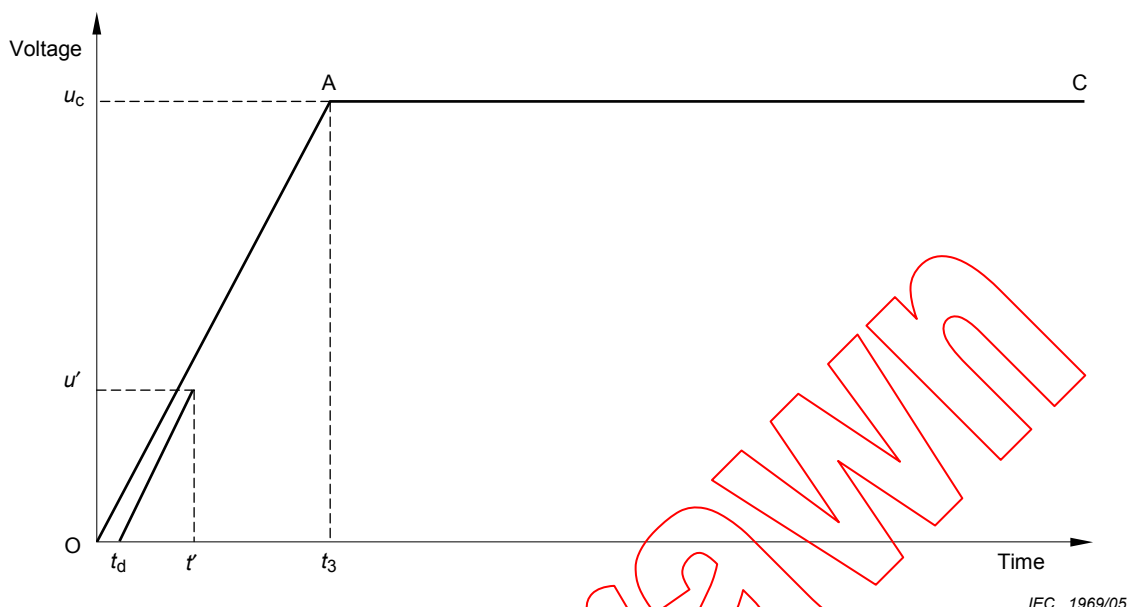


Figure 3 – Representation of a specified TRV by a two-parameters reference line and a delay line

4.11 Time-current characteristics

The time-current characteristics of fuse-links are based on applying current to a new and unloaded fuse-link in a fuse-base specified by the manufacturer and connected to the test circuit with conductor sizes and lengths as specified in 6.5.1.2.

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 6.7.2.

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.

NOTE It is recommended that the values 2,8 and 5,6 be used 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 $\pm 20\%$. If minimum values are used, the tolerance shall not exceed $+50\%$;
- the type and rating of the fuse-link to which the curve data apply;
- the time range as specified in 6.7.2.2. 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.

For the purpose of coordination between fuses or between fuses and other protective devices, the relevant time-current characteristics may be employed for periods down to 0,1 s.

Where higher fault levels result in fuse operation in times less than 0,1 s, the relevant pre-arcing I^2t and operating I^2t data (see notes 1 and 2 of 3.1.11) may be used.

4.12 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 6.6.

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

4.13 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 standard, 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.

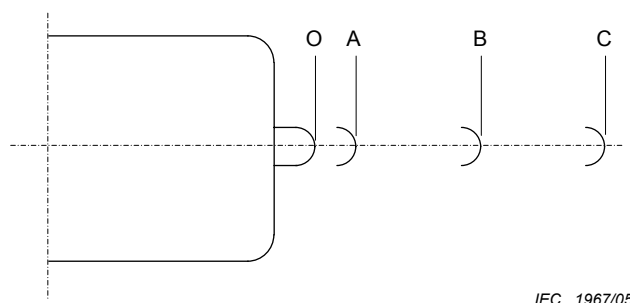
The presentation of I^2t values may be in simple tabular or diagrammatic form (for example, histograms) or may employ graphical presentation with prospective current as abscissa and I^2t as ordinate, both scales being logarithmic with preferred dimensions as in 4.12.

The I^2t values determined as a part of the breaking type tests specified in 6.6 shall not be greater (for operating I^2t) or less (for pre-arcing I^2t) than the values stated by the manufacturer.

4.14 Mechanical characteristics of strikers

Strikers may be 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 4](#)) of their travel and 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.

The mechanical characteristics of the strikers are given in [Table 11](#).



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Key

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

Figure 4 – Various stages of the striker travel

Table 11 – Mechanical characteristics of strikers

Type	Energy	Mechanical characteristics					
		Values of		Actual travel		Minimum withstand force	Maximum duration of travel
		Free travel	Further travel during which energy must be delivered	Min.	Max.		
		(OA) (footnote a)	(AB) (footnote a)	(OB) (footnote a)	(OC) (footnote a)		
	J	mm	mm	mm	mm	N	ms
Light	$0,3 \pm 0,25$	2	8	10	30	Not applicable	50
Medium	$1 \pm 0,5$	4	16	20	40	20	50
Heavy	2 ± 1	4	6	10	16	40	50
^a See Figure 4. ^b Duration of travel is defined as the time from commencement of arcing to the time when travel OB is reached. The additional 50 ms required for the arcing withstand (4.15.2) is to allow for the switch operating time.							

4.15 Special requirement for Back-Up fuses intended for use in switch-fuse combination according to IEC 62271-105

4.15.1 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 5.1.3) at currents just below fuse minimum breaking current is longer in duration than the tripping time of the associated switch.

4.15.2 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.

Procedure to define these temperature and current values is given in 7.6.2. In the case of homogeneous series, it is sufficient to perform the test on the fuse having the highest current rating.

4.15.3 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. Testing procedure is described in 7.6.3.

5 Design, construction and performance

5.1 General requirements with respect to fuse operation

5.1.1 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 6.6 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 Clause 8).

5.1.2 Standard conditions of use

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

- the a.c. component is not lower than the rated minimum breaking current and not higher than the rated maximum breaking current;
- the power-frequency recovery voltage is not higher than that specified in [Table 13](#) (for special conditions, see 9.3.4);
- the prospective transient recovery voltage is within the limits represented by the tests specified in 6.6.1.2;
- the frequency is between 48 Hz and 62 Hz;
- the power factor is not lower than that represented by the tests specified in [Table 13](#);
- 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 6.6.1.2.

NOTE 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 6.6.1.2.2).

5.1.3 Standard conditions of behaviour

According to the conditions of use indicated in 5.1.2, the behaviour of the fuse shall be as follows.

- a) A powder-filled fuse-link shall not emit flame or powder, although a minor emission of flame from a striker or indicating device is permissible, provided this does not cause breakdown or significant electrical leakage to earth.
- b) After the fuse has operated, the components of the fuse, apart from those intended to be replaced after each operation, shall be in the original state. It shall be possible to remove the fuse-link in one piece after operation.
- 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 4.14 and shall operate fully.
- d) Operation shall not generate switching voltages higher than the values specified in 4.9.
- 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.

5.2 Identifying markings

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

NOTE 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;
 - 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).

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 oil, unless this information is included in the type designation or identification code.

5.3 Dimensions

Annex D contains a collection and classification of types and dimensions specified in the various existing national standards.

6 Type tests

6.1 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 or under special specified conditions. Type tests are made on samples to check the specified characteristics of all fuses of the same type.

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

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

For convenience of testing, and with the previous consent of the manufacturer, the values prescribed for the tests, particularly the tolerances, can be 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 standard are, in principle, type tests, and methods of sampling for acceptance tests are not given.

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

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

6.2 List of type tests

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

- dielectric tests (fuse-base only);
- temperature-rise tests and power-dissipation measurement;
- breaking tests;
- tests for time-current characteristics;
- tests of strikers.

6.3 Common test practices for all type tests

6.3.1 General

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

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

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

6.3.3 Mounting of fuses

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

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

6.4 Dielectric tests

6.4.1 Test practices

Dielectric test practices shall be as specified in 6.3 and as follows.

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

6.4.1.1 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.

6.4.1.2 Electrical connections

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

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

The test voltage specified in Tables 4 and 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.

NOTE 1 For multi-pole arrangements of fuses

- 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.

NOTE 2 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.

6.4.3 Atmospheric conditions during test

The test shall be made at atmospheric conditions as near as possible to the standard conditions specified in 11.1 of IEC 60060-1.

The correction factors for air density and for air humidity, as given in 11.2.1 and 11.2.2 of IEC 60060-1, may be used for fuses pending further information.

6.4.4 Lightning impulse voltage dry tests

Fuses shall be subjected to lightning impulse voltage dry tests with 1,2/50 impulses in accordance with Section 6 of IEC 60060-1.

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

- at the rated withstand voltage to earth and between poles for all the test conditions a) of 6.4.2;
- at the rated withstand voltage to earth and between poles for the test condition b) of 6.4.2 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 6.4.2 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 (see 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.

6.4.5 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 Tables 4 and 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 a) of 6.4.2;
- at the rated withstand voltage to earth and between poles for the test conditions b) of 6.4.2 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 6.4.2 if isolating properties are assigned to the fuse-base.

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

6.4.6 Power-frequency wet tests

Outdoor type fuses shall be subjected to power-frequency voltage wet tests under the same conditions as specified in 6.4.5 except for the duration, which is 1 min. 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 Clause 9 of IEC 60060-1.

6.5 Temperature-rise tests and power-dissipation measurement

6.5.1 Test practices

Temperature-rise tests and power-dissipation measurement shall be made as specified in 6.3 on one fuse and as follows.

6.5.1.1 Test sample

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

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

6.5.1.2 Arrangement of the equipment

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

The fuse in air shall be mounted in the most unfavourable position within the instructions specified by the manufacturer and connected to the test circuit by bare copper conductors as follows: each conductor shall be approximately 1 m (3 ¼ ft) long, mounted in a plane parallel to the mounting surface of the fuse, but it may be in any direction in this plane. The sizes of the leads are given in Table 12.

Table 12 – Electrical connection to the test circuit – Conductor sizes

Current rating of the fuse-link (footnote a) A		Size of bare copper conductors (footnote 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	1000	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.		

Oil-tight fuse-links for use in switchgear shall be tested in an oil-filled enclosure designed to simulate service conditions. The volume of this enclosure shall be about 30 times the volume of the fuse-link under test. The fuse-link shall be immersed in such a manner that the oil is equally distributed around the fuse-link. Annex C gives an example of preferred testing arrangements for fuse-links up to 200 A in accordance with data sheet II of Annex D. The test conductors external to the tank shall be arranged as given in the preceding paragraph, with the sizes as given in Table 12.

Normal clearances need not be provided.

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

The temperature rise of the various parts of the fuse shall not exceed the values specified in Clause 4.

6.5.2 Measurement of temperature

6.5.2.1 Temperature of fuse parts

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

The surface temperature of a component immersed in a liquid dielectric shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured below, close to the device (that is in the liquid that cools the device).

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

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

6.5.2.2 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 means of at least three thermometers, thermocouples or other temperature-detecting devices equally distributed around the fuse at about the average height of its current-carrying parts at a distance of about 1 m from the fuse. The thermometers or thermocouples shall be protected against air currents and undue influence of heat.

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

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 h. If this is not possible because of unfavourable temperature conditions 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.

6.5.3 Measurement of power dissipation

Fuses intended for use in enclosures may require derating (see 9.3.2 and Annex F). To facilitate this derating, measurement of the power dissipation shall be made as follows.

- a) The measurement of power dissipation can be made during the temperature-rise test. Two values shall be measured, one at 50 % and the second at 100 % of the rated current of the fuse-link. The voltage shall be measured on the fuse-link contacts as close as possible to the point of contact with the immediately mating contact piece. Measurement shall be made when the power dissipation (the temperature) has reached a steady-state value for the current value considered. The power dissipation is expressed in watts.

NOTE This requirement applies only to fuses intended for use in enclosures. For other fuses, see 7.1 and 7.3.

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

6.6 Breaking tests

6.6.1 Test practices

Breaking test practices shall be as specified in 6.3 and as follows.

6.6.1.1 Description of tests to be made

Tests shall be made according to the instructions given in [Table 13](#) 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 below).

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 6.6.1.3).

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 in assessing compliance with this requirement are discussed in Annex G.

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 r.m.s. values of the a.c. component of the current.

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

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 13) except 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 6.6.4 for the requirements to be met and tests to be made.

A homogeneous series 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 6.6.5 for the requirements to be met.

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

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

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

where

I_2 is the prospective current for Test Duty 2;

i_1 is the instantaneous current at instant of melting in Test Duty 1;

I_1 is the prospective current in Test Duty 1.

- b) By taking between three and four times the current which corresponds to a pre-arcing time of one half-cycle on the time-current characteristic (see 6.7 and 4.11). If a time-current characteristic curve exists for virtual times less than one half-cycle, it is preferable to use the current corresponding on this time-current characteristic to a time of 0,08 normal half-cycle.

Table 13 – Breaking tests – Parameters

Parameters	Test duties		
	1 (footnote a)	2	3
Power-frequency recovery voltage	(0,87 × rated voltage) $^{+5}_{0}$ %		Rated voltage $^{+5}_{0}$ %
Prospective TRV characteristics	See 6.6.1.2		Not specified
Power factor	From 0,07 to 0,15 (footnote b)		0,4 to 0,6
Prospective current (r.m.s. value of the a.c. component)	I_1 $^{+5}_{0}$ %	I_2	I_3 $^{0}_{-10}$ % (footnote c)
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
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 (footnote d)	
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 When the manufacturer agrees, the lower limit does not apply. ^c 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. ^d 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.			

6.6.1.2 Characteristics of the test circuit

6.6.1.2.1 General

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 Figures 7 and 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. Where some distortion is unavoidable, it shall not be such as to necessitate the open-circuit voltage to be more than 107 % of the voltage corresponding to the required recovery voltage on Test Duties 1 and 2, as specified in 6.6.1.1.

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 spark-over occurs during the normal interrupting operation of the fuse, since a parallel path through protective equipment may reduce the duty on the fuse.

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

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

NOTE It is stressed that the extent by which the envelope may exceed the specified reference line requires the consent of the manufacturer (see the fourth paragraph of 6.1).

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.

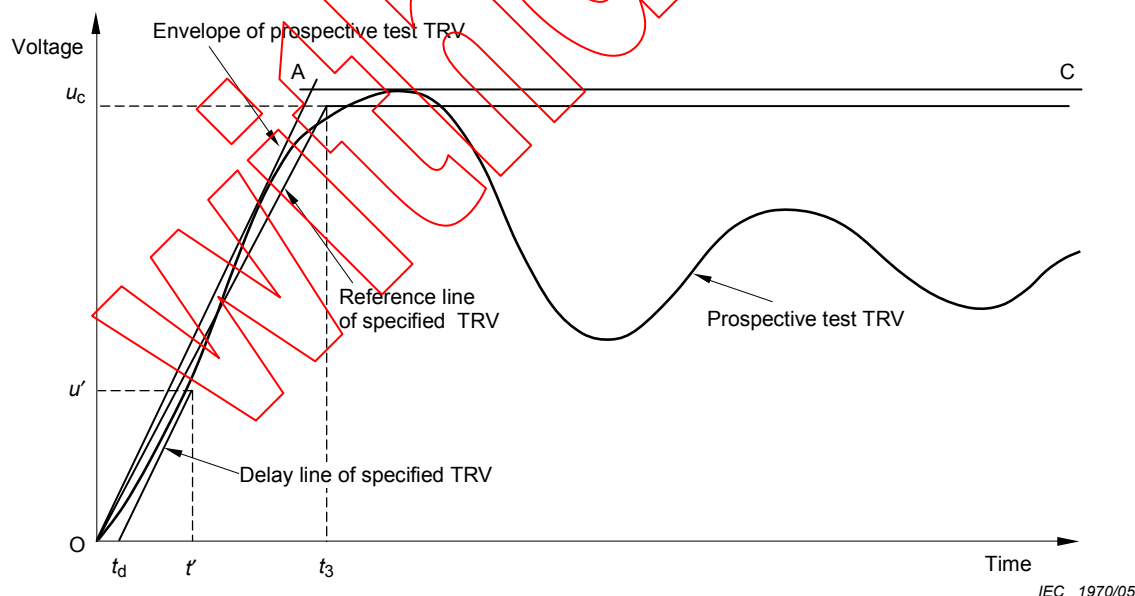


Figure 5 – Example of a two-parameters reference line for a TRV complying with the conditions of the type test

6.6.1.2.2 TRV for Test Duty 1

In principle, the tests are made with the standardised values of TRV specified in 4.10. 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 4.10 and an initial portion not crossing the specified delay line. All the tests of Test Duty 1 shall be made in this new circuit.

6.6.1.2.3 TRV for Test Duty 2

Tests shall be made with the values of prospective TRV specified in Tables 14 and 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 1 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).

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

Table 15 – TRV for Test Duty 2 – Series II

Rated voltage	Basic parameters		Rate of rise
	Peak voltage	Time coordinate	
U_r	u_c (footnote a)	t_3	u_c/t_3
kV	kV	μs	kV/ μs
2,75	5	111 – 148	0,045 – 0,033
5,5	10	138 – 184	0,072 – 0,054
8,25	15,4	162 – 216	0,095 – 0,071
15	27,5	198 – 264	0,138 – 0,104
15,5	28,4	201 – 268	0,141 – 0,106
25,8	47	273 – 364	0,172 – 0,129
38	69,5	333 – 444	0,208 – 0,156
48,3	89	381 – 508	0,233 – 0,175
72,5	133	504 – 672	0,265 – 0,199

^a $u_c = 1,5 \times 1,5 \times \sqrt{2/3} U_r$

6.6.1.2.4 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.

6.6.1.3 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 13 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 the rated current I_r ;
 - 0,2 to 0,3 lagging if the cross-over current I_t is between 25 times the 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 in assessing compliance with this requirement are discussed in Annex G.

6.6.1.4 Test samples

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

6.6.1.5 Arrangement of the equipment

6.6.1.5.1 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.

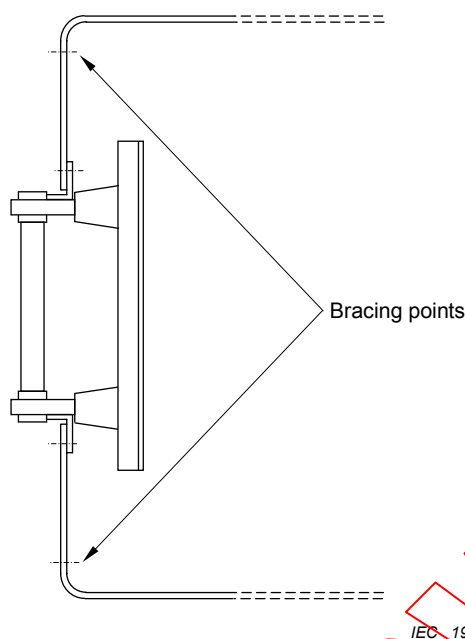


Figure 6 – Breaking tests – Arrangement of the equipment

6.6.1.5.2 Fuses intended for use in oil-filled enclosures

Test Duties 1, 2, 3, and I_t may be performed in air or in an oil-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 an oil-filled enclosure, using an arrangement of test conductors suitable for that enclosure. The oil-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.

6.6.2 Test procedure

6.6.2.1 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 Figures 7 and 8.

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

NOTE 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.

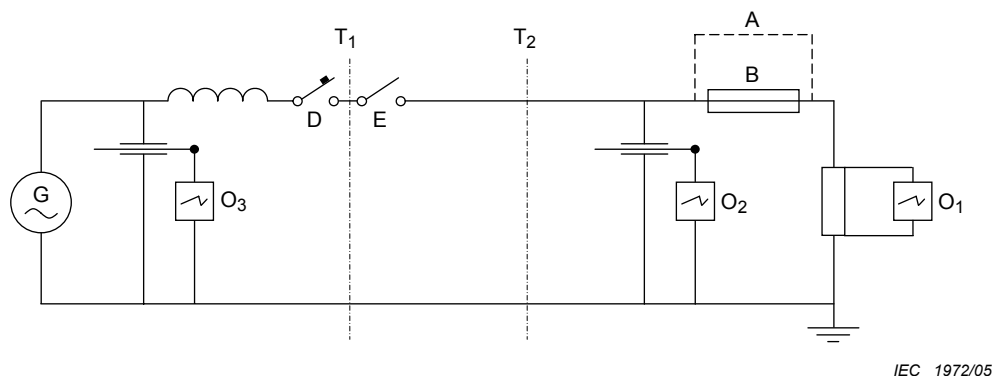
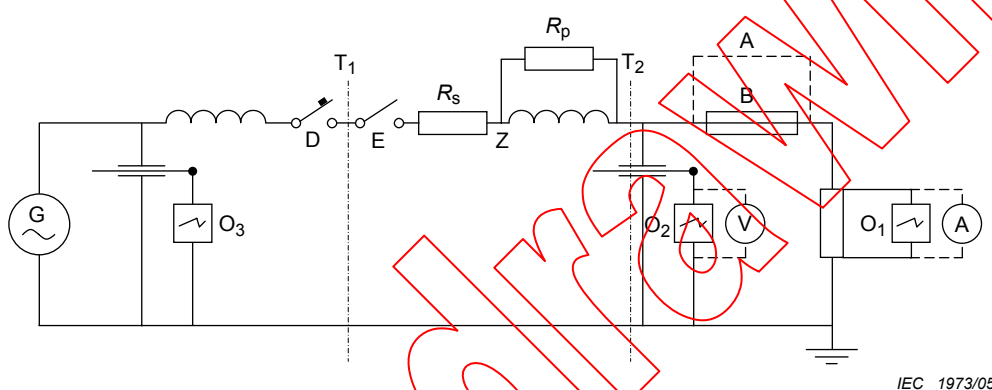


Figure 7 – Breaking tests – Typical circuit diagram for Test Duties 1 and 2



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 – 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

6.6.2.2 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 13.

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, current may be measured by an ammeter as an alternative or an addition to an oscillograph or similar measuring system.

After the fuse has operated, recovery voltage shall be maintained across the fuse for the period specified in Table 13. The first few cycles shall be recorded by an oscillograph or similar system and the remainder may be observed on a voltmeter.

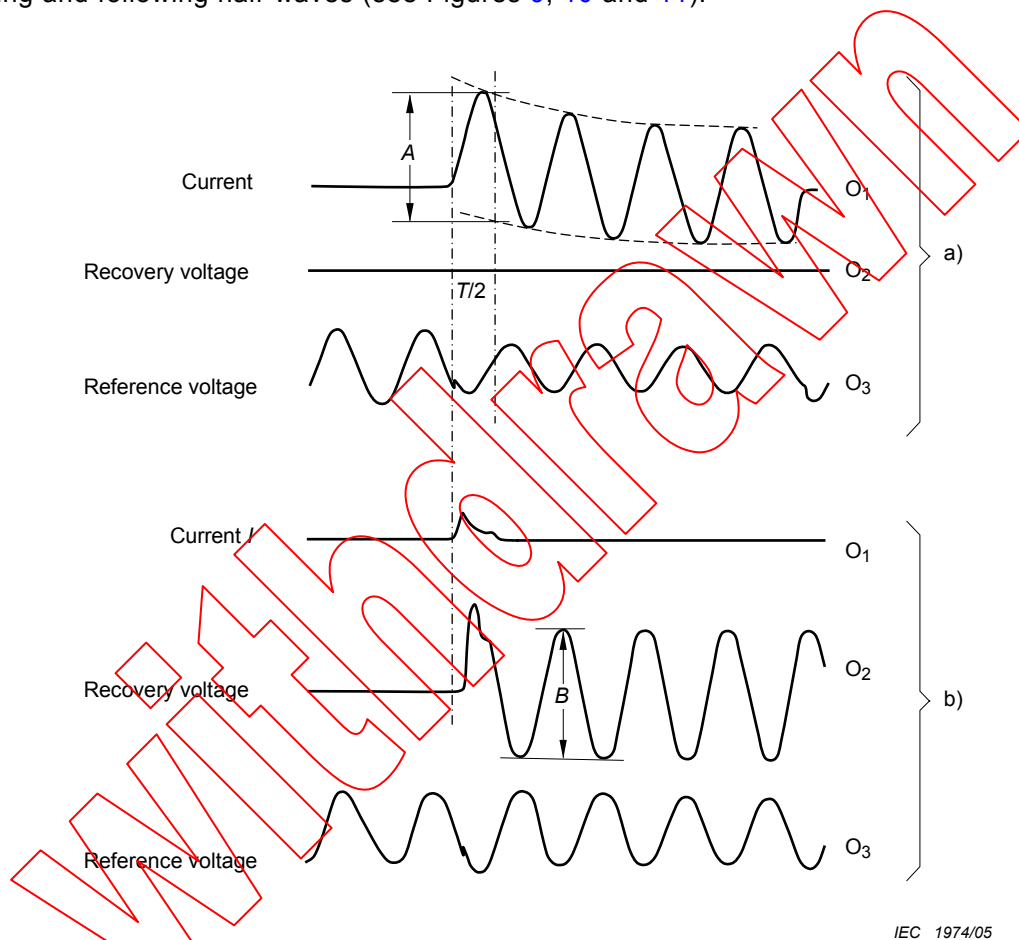
During this period, the power frequency may fall below the specified minimum value.

6.6.2.3 Interpretation of oscillograms

For Test Duties 1 and 2, the prospective breaking current shall be the r.m.s. value of the a.c. component of the current, measured one half-cycle after the initiation of short circuit in the calibration test (see Figures 9 and 10).

For Test Duty 3 and I_t tests, the breaking current shall be the r.m.s. 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 Figures 9, 10 and 11).



IEC 1974/05

Key

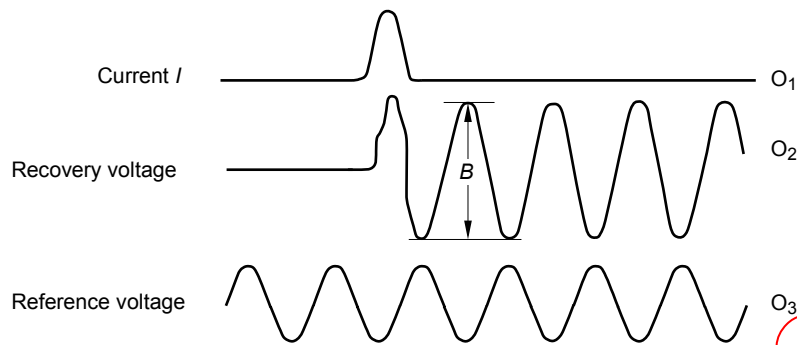
- O₁ Current measurement
- O₂ Recovery voltage measurement
- O₃ Reference voltage measurement
- a) Calibration test
- b) Breaking test

RMS value of the a.c. component of prospective breaking current $I = \frac{A}{2\sqrt{2}}$

Recovery voltage $U = \frac{B}{2\sqrt{2}}$

NOTE Figures 9, 10 and 11 are for illustration; the currents are not drawn to the same scale.

Figure 9 – Breaking tests – Interpretation of oscillograms for Test Duty 1

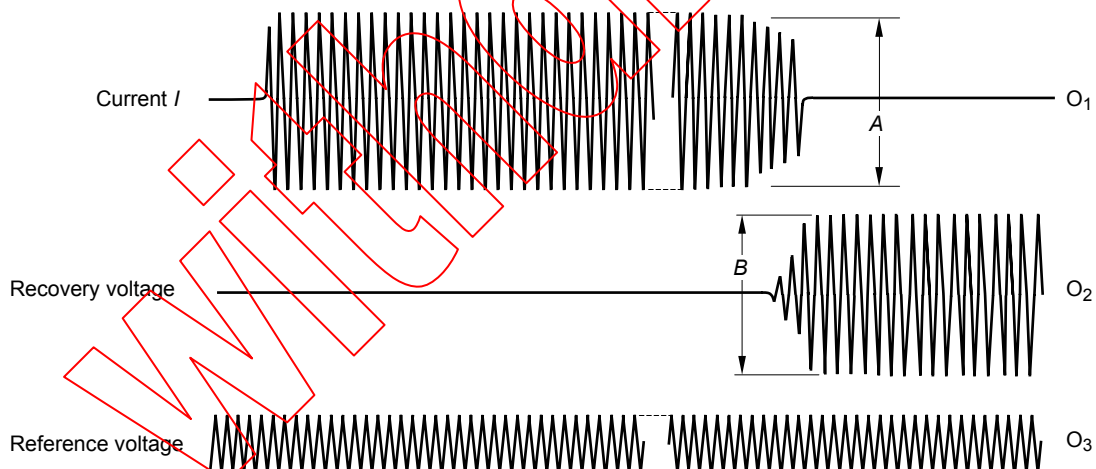


IEC 1975/05

Key

- O₁ Current measurement
- O₂ Recovery voltage measurement
- O₃ Reference voltage measurement

Figure 10 – Breaking tests – Interpretation of oscillograms for Test Duty 2 (calibration traces as in a) of Figure 9)



IEC 1976/05

Key

- O₁ Current measurement
- O₂ Recovery voltage measurement
- O₃ Reference voltage measurement

Figure 11 – Breaking tests – Interpretation of oscillograms for Test Duty 3

6.6.2.4 Parameters to be used for tests

The parameters to be used when making the tests are given in [Table 13](#).

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

6.6.3 Alternative test methods for Test Duty 3

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 must occur before arcing commences.

6.6.3.1 Circuit requirements

Circuit requirements are as follows.

- a) A low-voltage power source able to cause the desired current to flow through the fuse under test and means for holding the current constant during the test.
- b) A high-voltage source as described in 6.6.1.2.

The value of the high-voltage current is the current I_3 as defined in 6.6.1.1.

- c) Provision for switching either manually or automatically from the low-voltage source to the high-voltage source at the desired instant during the tests.

The time interval during which the current is interrupted shall not exceed 0,2 s. There shall be no significant asymmetry in the current at the instant of changeover to the high-voltage source.

In general, the changeover should take place while at least one fuse element is still carrying current. For a multi-elemented fuse this would be in the period where elements are melting successively, as shown by step increases in the voltage developed across the fuse.

- d) With the consent of the manufacturer, it is permissible for the changeover to be delayed until all the fuse elements (but not the striker element, where fitted) have melted. All other parameters given in c) still apply.

This procedure is of value in cases where it is difficult to detect the onset of element melting, or where the value of pre-arcing current has to be significantly higher than the chosen value of Test Duty 3 current (see 6.6.3.2).

However, since this method is held to be more onerous for the fuse than method c), in case of failure, it is permissible to repeat the Test Duty 3 tests using method c) since the latter is closer to actual service conditions.

6.6.3.2 Value of pre-arcing test current for Test Duty 3

Values are as follows.

- a) For tests on Back-Up fuses, where the pre-arcing time is less than 1 h, the low-voltage source should be set to the value I_3 and maintained at this value throughout the test.
- b) For General-Purpose fuses, where a minimum time to melt of 1 h is required, the current of the low-voltage source is set to I_3 , but it may be increased after 1 h by up to 15 % above I_3 to induce melting.
- c) For those Full-Range fuses, where the requirement is for an I_3 value equal to fuse rated current, the low-voltage source may be set to a higher value than I_3 throughout the low-voltage part of the test in order to avoid an unnecessarily long testing time, provided that

the resulting pre-arcing time is not less than 1 h. However, the low-voltage current shall not exceed I_3 by more than 42 % during this pre-arcing period.

After the elapse of 1 h, the low-voltage current may be further increased by up to 15 % in order to induce melting.

If this higher value still results in an inconveniently long testing time, it is permissible to install the fuse-link in an enclosure with restricted cooling – again provided a melting time of at least 1 h is obtained.

In cases where the use of such an enclosure is insufficient to cause melting to occur in a reasonable time, then the test method given in Annex E may be used.

6.6.4 Breaking tests for fuse-links of a homogeneous series

6.6.4.1 Characteristics of fuse-links of a homogeneous series

Fuse-links are considered as forming a homogeneous series when their characteristics comply with the following.

- a) Rated voltage, maximum breaking current and frequency shall be the same.
- b) All materials shall be the same, including filling material and its grain distribution.
- c) All dimensions of the fuse-link, except the cross-section and the number of fuse element(s) as detailed below from items d) to h), shall be the same.
- d) In any fuse-link, all the main fuse elements shall be identical.
- e) The law governing the variation of the cross-section of individual fuse elements along their length shall be the same.
- f) All variations in thickness, width and number shall be monotonous¹ with respect to rated current. Thus, balancing an increase in cross-section by reducing the number of fuse elements and vice versa is not allowed.
- g) The variation in distance, if any, between individual fuse elements and the variation in distance, if any, between fuse element(s) and fuse barrel shall be monotonous² with respect to the rated current.
- h) A special fuse element used for an indicator or striker is exempt from items e) and f) above, but this element shall be the same for all the fuse-links.

6.6.4.2 Test requirements

In a homogeneous series of fuse-links, breaking tests need only be made in accordance with [Table 16](#).

¹ Monotonous function: a function continually varying in the same direction for a given direction of the variable.