

High-voltage fuses —

Part 1: Current-limiting fuses

The European Standard EN 60282-1:2002 has the status of a British Standard

ICS 29.120.50

National foreword

This British Standard is the official English language version of EN 60282-1:2002. It is identical with IEC 60282-1:2002, including corrigendum August 2002. It supersedes BS EN 60282-1:1996 which will be withdrawn on 2005-05-01.

The UK participation in its preparation was entrusted to Technical Committee PEL/32, Fuses, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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English version

High-voltage fuses
Part 1: Current-limiting fuses
(IEC 60282-1:2002)

Fusibles à haute tension
Partie 1: Fusibles limiteurs
de courant
(CEI 60282-1:2002)

Hochspannungssicherungen
Teil 1: Strombegrenzende Sicherungen
(IEC 60282-1:2002)

This European Standard was approved by CENELEC on 2002-05-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

The text of document 32A/207/FDIS, future edition 5 of IEC 60282-1, prepared by SC 32A, High-voltage fuses, of IEC TC 32, Fuses, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60282-1 on 2002-05-01.

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The following dates were fixed:

- latest date by which the EN has to be implemented
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- latest date by which the national standards conflicting
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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes A, E and ZA are normative and annexes B, C, D and F are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60282-1:2002 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60890 NOTE Harmonized as HD 528 S2:1997 (not modified).

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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 60420.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60282. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60282 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(151):2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*

IEC 60050(604):1987, *International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation*

IEC 60056:1987, *High-voltage alternating-current circuit-breakers*

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

IEC 60071-1:1993, *Insulation coordination – Part 1: Definitions, principles and rules*

IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*

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

IEC 60420:1990, *High-voltage alternating current switch-fuse combinations*

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 60694:1996, *Common specifications for high-voltage switchgear and controlgear standards*

IEC 60787:1983, *Application guide for the selection of fuse-links of high-voltage fuses for transformer circuit application*

ISO 148-2:1998, *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 (3 300 ft).

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 (3 300 ft). When fuses incorporating external insulation are required for use at altitudes above 1 000 m (3 300 ft), one or other of the following procedures should be adopted.

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

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

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

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

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

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

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

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

- c) The ambient air is not excessively (or abnormally) polluted by dust, smoke, corrosive or flammable gases, vapour or salt.
- d) For indoor installations, the conditions of humidity are under consideration but, in the meantime, the following figures can be used as a guide:
- the average value of the relative humidity, measured during a period of 24 h, does not exceed 95 %;
 - the average value of the vapour pressure, for a period of 24 h, does not exceed 22 mbar;
 - the average value of the relative humidity, for a period of one month, does not exceed 90 %;
 - the average value of the water vapour pressure, for a period of one month, does not exceed 18 mbar.

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 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.

2.3 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 Definitions

For the purpose of this part of IEC 60282, certain definitions taken from IEC 60050(151), IEC 60050(441) and IEC 60050(604), together with the following 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

[IEV 151-16-08]

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

3.1.2

rating

set of rated values and operating conditions

[IEV 151-16-11]

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

[IEV 441-17-01, modified]

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

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

[IEV 441-17-06]

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

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

[IEV 441-17-12, modified]

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

3.1.8**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 1Ω of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in $A^2 \times s$.

[VEI 441-18-23]

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.

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 (of 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.

3.1.22**power acceptance of a fuse-base**

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

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

[IEV 441-18-02]

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

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 8.3.4.

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.

3.3.9**self-restoring insulation**

insulation which completely recovers its insulating properties after a disruptive discharge

[IEV 604-03-04]

4 Ratings and characteristics

- a) Ratings of the fuse-base
 - 1) Rated voltage (4.1)
 - 2) Rated current (4.4)
 - 3) Rated insulation level (power-frequency, dry, wet and impulse withstand voltages) (4.2)
- b) Ratings of the fuse-link
 - 1) Rated voltage (4.1)
 - 2) Rated current (4.5)
 - 3) Rated maximum breaking current (4.7.1)
 - 4) Rated frequency (4.3)
 - 5) Rated minimum breaking current for back-up fuses and class (4.7.2)
 - 6) Rated TRV (4.9)
- c) Characteristics of the fuse
 - 1) Temperature rise limits (4.6)
- d) Characteristics of the fuse-link
 - 1) Class (3.3.2 and 4.7.2)
 - 2) Switching voltages (4.8)
 - 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 of full-range fuses (4.10)

4.1 Rated voltage

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

NOTE This rated voltage is equal to the highest voltage for the equipment (see 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

4.2 Rated insulation level (of a fuse-base)

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

Two levels of dielectric withstand are recognized for a fuse-base according to European practice. These are termed "List 1" and "List 2" and relate to different severities of application and corresponding different values of test voltage for the dielectric tests (see 8.3.6).

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 (1 013 mbar) 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 (1 013 mbar) 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 (dry and wet) kV (r.m.s.)	
	List 1 kV (peak)		List 2 kV (peak)			
	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)				Rated power-frequency withstand voltage					
	kV (peak)				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.

4.3 Rated frequency

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

4.4 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.

4.5 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.

4.6 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.

NOTE For fuses used in enclosures, see 6.5.3, 8.3.2 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.

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	(note 1)	
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	(note 1)	
B Contacts in oil (copper or copper alloy):		
1 Spring-loaded contacts		
– bare	80	40
– silver-, tin- or nickel-coated	90	50
– other coatings	(note 1)	
2 Bolted contacts		
– bare	80	40
– silver-, tin- or nickel-coated	100	60
– other coatings	(note 1)	
C Bolted terminals in air:		
– bare	90	50
– silver-, nickel- or tin-coated	105	65
– other coatings	(note 1)	
D Metal parts acting as springs		
	(note 2)	
E Materials used as insulation and metal parts in contact with insulation of following classes^a:		
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	(note 3)	
F Oil (notes 4 and 5)		
	90	50
G Any part of metal or of insulating material in contact with oil except contacts and springs		
	100	60
NOTE 1 If the manufacturer uses coatings other than those indicated in table 6, the properties of these materials should be taken into consideration.		
NOTE 2 The temperature or the temperature rise should not reach such a value that the elasticity of the metal is impaired.		
NOTE 3 Limited only by the requirement not to cause any damage to surrounding parts.		
NOTE 4 At the upper part of the oil.		
NOTE 5 Special consideration should be given with regard to vaporization and oxidation when low-flash-point oil is used.		
^a Classes according to IEC 60085.		

4.7 Rated breaking capacity

4.7.1 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.

4.7.2 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.

4.8 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 kV	Maximum switching voltage kV	Rated voltage kV	Maximum switching voltage kV
3,6	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
36	120	22 to 25,8	117
		27	123
		38	173

NOTE 1 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 4.2).

NOTE 2 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 13).

4.9 Rated transient recovery voltage (rated TRV)

The rated transient recovery voltage related to the rated maximum breaking current (in accordance with 4.7) 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 ^a	Voltage coordinate ^b	Time coordinate ^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

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

^a $t_d = 0,15 t_3$
^c $t' = (0,15 + 1/3) t_3$

for $U_r < 52$ kV

^a $t_d = 0,05 t_3$
^c $t' = (0,05 + 1/3) t_3$

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 ^a	Voltage coordinate ^b	Time coordinate ^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
$u_c = 1,4 \times 1,5 \times \sqrt{2/3} U_r$ $^b u' = 1/3 u_c$ $\left. \begin{array}{l} ^a t_d = 0,15 t_3 \\ ^c t' = (0,15 + 1/3) t_3 \end{array} \right\} \text{ for } U_r \leq 48,3 \text{ kV}$ $\left. \begin{array}{l} ^a t_d = 0,05 t_3 \\ ^c t' = (0,05 + 1/3) t_3 \end{array} \right\} \text{ for } U_r > 48,3 \text{ kV}$						

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 6.6.1.2.1. For testing at breaking current less than the rated value, other values of transient recovery voltage are specified (see 6.6.1.2.2).

4.9.1 Representation of TRV

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

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

4.9.2 Representation of rated TRV

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

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

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

4.10 Maximum application temperature of full-range fuses

For full-range fuses intended for use in ambient temperature above 40 °C, the manufacturer shall provide data in respect of the maximum temperature for which the fuse is designed. This is the maximum temperature of the surrounding medium in contact with the fuse-link at which the fuse is suitable for use.

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 recognized as an alternative standard.

The representation shall be made on standardized 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 ± 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 4.11.

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 12) 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.

Table 11 – Mechanical characteristics of strikers

Type	Energy	Mechanical characteristics					
		Values of		Actual travel		Minimum withstand force	Maximum duration of travel (see note)
		Free travel (OA)*	Further travel during which energy must be delivered (AB) ^a	Min. (OB)*	Max. (OC)*		
	J	mm	mm	mm	mm	N	ms
Light	0,3 ± 0,25	2	8	10	30	Not applicable	100
Medium	1 ± 0,5	4	16	20	40	20	100
Heavy	2 ± 1	4	6	10	16	40	100
NOTE Duration of travel is defined for actual fuse-links as the time from commencement of arcing to the time when travel OB is reached. For dummy fuses, it is the time from application of voltage until travel OB is reached.							
^a See figure 12.							

4.15 Special requirement for back-up fuses intended for use in switch-fuse combination according to IEC 60420

For such applications, it is necessary to ensure that

- 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;
- 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.

4.15.1 Maximum body temperature under pre-arcing conditions

For back-up fuses intended for use in striker-tripped fuse-switch combinations according to IEC 60420, 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 7.1.5. In the case of homogeneous series, it is sufficient to perform the test on the fuse having the highest current rating.

4.15.2 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 7.1.5.