IEC 60269-6

Edition 1.0 2010-09

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Low-voltage fuses –
Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

Fusibles basse tension –
Partie 6: Exigences supplémentaires concernant les éléments de remplacement utilisés pour la protection des systèmes d'énergie solaire photovoltaïque

IEC 60269-6:2010

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CONTENTS

FOREWORD 4
1 General 6
1.1 Scope and object 6
1.2 Normative references 6
2 Terms and definitions, ... 7
2.2 General terms 7
3 Conditions for operation in service 10
3.4 Voltage 10
3.4.1 Rated voltage 10
3.5 Current 10
3.5.1 Rated Current 10
3.6 Frequency, power factor and time constant 10
3.6.1 Frequency 10
3.6.2 Power factor 10
3.6.3 Time constant 10
3.10 Temperature inside an enclosure 11
4 Classification 11
5 Characteristics of fuses 11
5.1 Summary of characteristics 11
5.1.2 Fuse-links 11
5.2 Rated voltage 11
5.5 Rated power dissipation of the fuse-link 11
5.6 Limits of time-current characteristics 11
5.6.1 Time-current characteristics, time-current zones 11
5.6.2 Conventional times and currents 11
5.6.3 Gates 12
5.7 Breaking range and breaking capacity 12
5.7.1 Breaking range and utilization category 12
5.7.2 Rated breaking capacity 12
6 Markings 12
6.2 Markings on fuse-links 12
7 Standard conditions for construction 12
7.5 Breaking capacity 12
8 Tests 13
8.1 General 13
8.1.4 Arrangement of the fuse and dimensions 13
8.1.5 Testing of fuse-links 13
8.3 Verification of temperature rise limits and power dissipation 14
8.3.1 Arrangement of the fuse-link 14
8.3.3 Measurement of power dissipation of the fuse-link 14
8.3.5 Acceptability of test results 14
8.4 Verification of operation 15
8.4.1 Arrangement of fuse-link 15
8.4.3 Test method and acceptability of test results 15
8.5 Verification of the breaking capacity 15
8.5.1 Arrangement of the fuse 15

AVA Documents
Document Sharing Hub
Full document details: IEC 60269-6 2010

8.5.5 Test method 16
8.5.8 Acceptability of test results 16
8.11 Mechanical and miscellaneous tests 17
Annex AA (normative) Examples of standardized fuse-links for the protection of solar photovoltaic energy systems 19
Annex BB (informative) Guidance for the protection of Photovoltaic string and array with fuse-links designed for PV applications 27
Bibliography 28

Figure 101 – Current of test cycling 18
Figure AA.1 – Fuse-links with cylindrical contact caps, type A 20
Figure AA.2 – Fuse-links with cylindrical contact caps type A with striker – Additional dimensions for sizes 14 × 51, 20 × 127 and 22 × 127 only 21
Figure AA.3 – North American cylindrical fuse-links with blade contacts – Sizes 61-600 A 22
Figure AA.4 – Fuse-links with blade contacts, type C, C referring IEC 60269-2 “Fuse system A (NH fuse system)” 24
Figure AA.5 – Fuse-links with long blade contacts, type D 26

Table 101 – Conventional times and currents for "gPV” fuse-links 12
Table 102 – Survey of complete tests on fuse-links and number of fuse-links to be tested 13
Table 103 – Survey of tests on fuse-links of the smallest rated current of a homogeneous series and number of fuse-links to be tested 14
Table 104 – Values for breaking-capacity tests on “gPV” fuse-links 16

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LOW-VOLTAGE FUSES –

Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

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International Standard IEC 60269-6 has been prepared by subcommittee 32B: Low-voltage fuses, of IEC technical committee 32: Fuses.

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

FDIS	Report on voting
32B/561/FDIS	32B/569/RVD

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

This part is to be used in conjunction with IEC 60269-1:2006, *Low-voltage fuses, Part 1: General requirements.*

This Part 6 supplements or modifies the corresponding clauses or subclauses of Part 1.

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Where no change is necessary, this Part 6 indicates that the relevant clause or subclause applies.

Tables and figures which are additional to those in Part 1 are numbered starting from 101.

Additional annexes are lettered AA, BB, etc.

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

A list of all parts of the IEC 60269 series, under the general title: *Low-voltage fuses*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability 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.

The contents of the corrigendum of December 2010 have been included in this copy.

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LOW-VOLTAGE FUSES –

Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

1 General

IEC 60269-1 applies with the following supplementary requirements.

Fuse-links for the protection of solar photovoltaic (PV) energy systems shall comply with all requirements of IEC 60269-1, if not otherwise indicated hereinafter, and shall also comply with the supplementary requirements laid down below.

NOTE The abbreviation “PV” (photovoltaic) is used in this document.

1.1 Scope and object

These supplementary requirements apply to fuse-links for protecting PV strings and PV arrays in equipment for circuits of nominal voltages up to 1 500 V d.c.

Their rated voltage may be up to 1 500 V d.c.

NOTE 1 Such fuse-links are commonly referred to as “PV fuse-links”.

NOTE 2 In most cases, a part of the associated equipment serves the purpose of a fuse-base. Owing to the great variety of equipment, no general rules can be given; the suitability of the associated equipment to serve as a fuse-base should be subject to agreement between the manufacturer and the user. However, if separate fuse-bases or fuse-holders are used, they should comply with the appropriate requirements of IEC 60269 series.

NOTE 3 PV fuse-links protect down stream inverter components such as capacitors or the discharge of capacitors back into the arrays or array wiring up to the rated breaking capacity.

The object of these supplementary requirements is to establish the characteristics of PV fuse-links in such a way that they can be replaced by other fuse-links having the same characteristics, provided that their dimensions are identical. For this purpose, this standard refers in particular to

a) the following characteristics of fuses:
   1) their rated values;
   2) their utilisation category;
   3) their temperature rises in normal service;
   4) their power dissipation;
   4) their time-current characteristics;
   6) their breaking capacity;
   7) their dimensions or size (if applicable).
b) type tests for verification of the characteristics of fuses;
c) the markings on fuses.

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.

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IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*[1]
Amendment 1 (2009)

IEC 60269-2, *Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to J*

ISO 3, *Preferred numbers – Series of preferred numbers*

2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60269-1 as well as the following apply.

2.2 General terms

2.2.101
photovoltaic fuse-link
fuse-link capable of breaking, under specific conditions, any current value within the breaking range (see 7.5)

NOTE A PV fuse-link operates under two main conditions:

– Short-circuit in a string or in an array which leads to a very low over-current.

– Short-circuit current supplied by the discharge of the PV inverter through a very low inductance. This short-circuit condition leads to a very high rate of rise of current equivalent to a low value of time constant, corresponding to Table 104.

2.2.102
photovoltaic cell
most elementary photovoltaic device which generate d.c. voltage by the absorption of photons

[IEC 61836, 3.1.43 a) and d) modified]

2.2.103
photovoltaic module
complete and environmentally protected assembly of interconnected PV cells

[IEC 61836, 3.1.43 f)]

2.2.104
photovoltaic array, array field, assembly, generator, panel, string, sub-array

2.2.104.1
photovoltaic array
assembly of mechanically integrated and electrically interconnected PV modules, PV panels or PV sub-array and its support structure

2.2.104.2
photovoltaic array field
aggregate of all PV arrays within a given PV system focusing on the mechanical arrangement of the PV technology

2.2.104.3
photovoltaic assembly
PV components that are installed outdoors and remote from its loads, including modules, support structure, foundation, wiring, tracking apparatus, and thermal control (were specified),

[1] *There is a consolidated edition 4.1 (2009) that includes IEC 60269-1(2006) and its amendment 1 (2009).*

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and including junction boxes, charge controllers and inverters depending on the assembly's installed configuration

2.2.104.4
photovoltaic generator
generator that uses the photovoltaic effect to convert sunlight into electricity

2.2.104.5
photovoltaic panel
PV modules mechanically integrated, pre-assembled and electrically interconnected

2.2.104.6
photovoltaic string
circuit of series-connected PV modules

2.2.104.7
photovoltaic sub-array
portion of a PV array that can be considered as a unit

[IEC 61836, 3.3.56 a), b), c), d), e), f) and g)]

2.2.105
inverter
electric energy converter that changes direct electric current to single-phase or polyphase alternating currents

[IEC 61836, 3.3.15] and [IEV 151-13-46]

2.2.106
junction box
closed or protected enclosure in which circuits are electrically connected

2.2.106.1
array junction box
junction box where PV strings are connected

2.2.106.2
generator junction box
junction box where PV arrays are connected

[IEC 61836, 3.2.16]

2.2.107
standard operating conditions
SOC
operating value of in-plane irradiance (1 000 Wm^{-2}), PV device junction temperature equals the nominal operating PV cell junction temperature (NOCT), and air mass (AM =1,5)

[IEC 61836, 3.4.16 d)]

2.2.108
standard test conditions
STC
reference values of in-plane irradiance ($G_{I,ref}$ = 1 000 Wm^{-2}), PV cell junction temperature (25 °C), and air mass (*AM*=1,5) to be used during the testing of any PV device

[IEC 61836, 3.4.16 e)]

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2.2.109
photovoltaic currents

2.2.109.1
load current
(symbol I_L) (unit : A)
electric current supplied to a load by a PV system

[IEC 61836, 3.4.39 a)]

2.2.109.2
maximum power current
(symbol I_{PMax}) (unit: A)
electric current at the conditions of maximum power

[IEC 61836, 3.4.42 a)]

2.2.109.3
rated current
(symbol I_R) (unit: A)
electric current produced by a PV device at a rated voltage under specified operating conditions

[IEC 61836, 3.4.69 c)]

2.2.109.4
short-circuit current
(symbol I_{SC}) (unit : A)
electric current at the output terminals of a PV device at a particular temperature and irradiance when the device output voltage is equal to or close to zero

[IEC 61836, 3.4.80]

2.2.110
photovoltaic voltages

2.2.110.1
load voltage
(symbol V_L) (unit: V)
voltage supplied across the terminals of a load by a PV system

[IEC 61836, 3.4.39 c)]

2.2.110.2
maximum power voltage
(symbol V_{PMax}) (unit: V)
voltage at the conditions of maximum power

[IEC 61836, 3.4.42 h)]

2.2.110.3
maximum power voltage under standard operating conditions
(unit: V)
voltage at the maximum power point of a PV device under standard operating conditions, SOC

[IEC 61836, 3.4.42 i)]

2.2.110.4
maximum power voltage under standard test conditions
(unit: V)
voltage at the maximum power point of a PV device under standard test conditions, STC

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[IEC 61836, 3.4.42 j)]

2.2.110.5
open-circuit voltage of PV devices
(symbol V_{OC}) (unit: V)
voltage at the output terminals of a PV device at a particular temperature and irradiance when the output electric current of the PV device is zero

2.2.110.6
open-circuit voltage under standard test conditions
(symbol $V_{OC\ STC}$)
open-circuit voltage as measured under standard test conditions, STC

[IEC 61836, 3.4.56 a)]

2.2.110.7
rated voltage
(symbol V_R) (unit: V)
voltage at which a generator is designed to generate maximum electricity under specified operating conditions

[IEC 61836, 3.4.69 k)]

3 Conditions for operation in service

IEC 60269-1 applies with the following supplementary requirements.

3.4 Voltage

3.4.1 Rated voltage

The rated d.c. voltage of a fuse-link shall exceed the maximum value of the open circuit voltage (V_{OC}) of the PV string. See Annex BB.2.1

3.5 Current

3.5.1 Rated Current

The rated current of a fuse-link shall exceed the maximum value of the current produced by the module. See Annex BB.3.1

3.6 Frequency, power factor and time constant

3.6.1 Frequency

Not applicable

3.6.2 Power factor

Not applicable

3.6.3 Time constant

The time constants expected in practice are considered to correspond to those in Table 104.

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3.10 Temperature inside an enclosure

Since the rated values of the fuse-links are based on specified conditions that do not always correspond to those prevailing at the point of installation, including the local air conditions, the user may have to consult the manufacturer concerning the possible need for re-rating.

4 Classification

IEC 60269-1 applies.

5 Characteristics of fuses

IEC 60269-1 applies with the following supplementary requirements.

5.1 Summary of characteristics

5.1.2 Fuse-links

a) Rated voltage (see 5.2)

b) Rated current (see 5.3 of IEC 60269-1)

c) Rated power dissipation (see 5.5)

d) Time-current characteristics (see 5.6)

e) Breaking range (see 5.7.1)

f) Rated breaking capacity (see 5.7.2)

g) Dimensions or size (if applicable)

h) Utilization category (see 5.7.1)

5.2 Rated voltage

For voltages up to 750 V, IEC 60269-1 applies; for higher voltages, the values should be selected from R5 series or, where not possible, from the R10 series of ISO 3.

5.5 Rated power dissipation of the fuse-link

In addition to the requirements of IEC 60269-1, the manufacturer shall indicate the power dissipation as a function of current for the range contained between 70 % to 100 % of the rated current.

5.6 Limits of time-current characteristics

5.6.1 Time-current characteristics, time-current zones

5.6.1.1 General requirements

The time-current characteristics depend on the design of the fuse-link, and, for a given fuse-link, on the ambient air temperature and the cooling conditions.

The manufacturer shall provide mean time-current characteristics in accordance with the conditions specified in 8.3.1.

5.6.2 Conventional times and currents

5.6.2.2 Conventional times and currents for "gPV"- fuse-links

The conventional times and currents are given in Table 101.

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Table 101 – Conventional times and currents for "gPV" fuse-links

Rated current A	Conventional time h	Conventional current	
		Type "gPV"	
		I_{nf}	I_f
$I_n \leq 63$	1	1,13 I_n	1,45 I_n
$63 < I_n \leq 160$	2		
$160 < I_n \leq 400$	3		
$I_n > 400$	4		

5.6.3 Gates

Not applicable.

5.7 Breaking range and breaking capacity

IEC60269-1 applies with the following supplementary requirement.

5.7.1 Breaking range and utilization category

The first letter indicates the breaking range:

– "g" fuse-links (full-range breaking capacity fuse-link).

The following letters indicate the utilization category:

– "gPV" indicates fuse-links with a full-range d.c. breaking capacity for photovoltaic energy systems.

5.7.2 Rated breaking capacity

The rated breaking capacity is based on type tests performed in a circuit containing linear components with mean value of applied voltage. The minimum value of the rated breaking capacity is 10 kA d.c.

6 Markings

IEC 60269-1 applies with the following supplementary requirements.

6.2 Markings on fuse-links

Subclause 6.2 of IEC 60269-1 applies with the following addition:

– utilization category "gPV".

7 Standard conditions for construction

IEC 60269-1 applies with the following supplementary requirement.

7.5 Breaking capacity

A fuse-link shall be capable of breaking, at rated d.c. voltage, any circuit having a prospective current between the conventional fusing current and the rated breaking capacity with time constant not greater than the values specified in Table 104.

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8 Tests

IEC 60269-1 applies with the following supplementary requirements.

8.1 General

8.1.4 Arrangement of the fuse and dimensions

The fuse-link shall be mounted open in surroundings free from draughts and, unless otherwise specified, in a vertical position (see 8.3.1).

8.1.5 Testing of fuse-links

The following Tables 102 and 103 replaces Tables 11, 12 and 13 of IEC 60269-1.

8.1.5.1 Complete tests

Before the tests are commenced, the internal resistance *R* of all samples shall be measured at an ambient-air temperature of (20 ± 5) °C with a measuring current of not more than 0,1 I_n. The value *R* shall be recorded in the test report.

A survey of the complete tests is given in Table 102.

8.1.5.2 Type test exemptions for fuse-links of a homogeneous series

Fuse-links having intermediate values of rated current of a homogeneous series are exempted from type tests if the fuse-link of the largest rated current has been tested to the requirements of 8.1.5.1 and if the fuse-link of the smallest rated current has been submitted to the tests indicated in Table 103.

Table 102 – Survey of complete tests on fuse-links and number of fuse-links to be tested

Test according to subclause			Number of samples								
			1	3	1	1	3	3	1	1	1
8.1.4	Dimensions		X		X					X	X
8.1.5.1	Resistance		X	X	X	X	X	X	X	X	X
8.3	Temperature rise and power dissipation		X								
8.4.3.2	Verification of rated current			X							
8.11.2.4	Verification of freedom from unacceptable levels of thermally induced drift After 50 temperature cycles, but tested at ambient temperature				X	X	X	X	X		
	8.4.3.1	Conventional non-fusing current (I_{nf})			X						
		Conventional fusing current (I_f)				X					
	8.5	No.1 Breaking capacity and operating characteristics (Table 104)					X				
		No.2 Breaking capacity and operating characteristics (Table 104)						X			
		No.5 Breaking capacity and operating characteristics (Table 104)							X		
8.11.2.5	Verification of functionality at temperature extreme (50 °C)									X	X
	a	Verification of ability to carry rated current at temperature extreme								X	

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Test according to subclause		Number of samples								
b	Conventional fusing current (I_f) at temperature extreme									X

Table 103 – Survey of tests on fuse-links of the smallest rated current of a homogeneous series and number of fuse-links to be tested

Test according to subclause			Number of samples				
			1	1	3	1	1
8.1.4	Dimensions		X			X	
8.1.5.1	Resistance		X	X	X	X	X
8.11.2.4	Verification of freedom from unacceptable levels of thermally induced drift and of functionality at temperature extremes After 50 temperature cycles, but tested at ambient temperature		X	X	X		
	8.4.3.1	Conventional non-fusing current (I_{nf})	X				
		Conventional fusing current (I_f)		X			
	8.5	No. 1 Breaking capacity and operating characteristics (Table 104)			X		
8.11.2.5	Verification of functionality at temperature extreme (50 °C)					X	X
	a	Verification of ability to carry rated current at temperature extreme				X	
	b	Conventional fusing current (I_f) at temperature extreme					X

8.3 Verification of temperature rise limits and power dissipation

8.3.1 Arrangement of the fuse-link

The fuse-link shall be mounted vertically in the conventional test arrangement.

For special fuse-links that cannot be accommodated in the conventional test arrangement, or for which this test arrangement is not applicable, special tests shall be performed according to the manufacturer's instructions and all pertinent data shall be recorded in the test report.

8.3.3 Measurement of power dissipation of the fuse-link

In addition to 8.3.3 of IEC 60269-1 the following applies.

The power dissipation test shall be made successively at least at 70 % and at 100 % of rated current.

8.3.5 Acceptability of test results

The temperature rise of the fuse-link shall not exceed the values specified in Table 5 of IEC 60269-1

The power dissipation of the fuse-link shall not exceed the values specified by the manufacturer.

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8.4 Verification of operation

8.4.1 Arrangement of fuse-link

The arrangement of the fuse-link for the verification of operation shall be as described in 8.1.4 and 8.3.1.

8.4.3 Test method and acceptability of test results

8.4.3.1 Verification of conventional non-fusing and fusing current

It is permissible to make the following tests at a reduced voltage:

a) the fuse-link is subjected to its conventional non-fusing current (I_{nf}) for a time equal to the conventional time specified in Table 101. It shall not operate during this time;

b) the fuse-link, after having cooled down to ambient temperature, is subjected to the conventional fusing current (I_f). It shall operate within the conventional time as specified in Table 101. The fuse-link shall operate without external effects or damage.

NOTE The tests in IEC 60269-6 are deemed to give satisfactory results for operation at 1,35 I_n within two hours in typical applications. If this test arrangement is not applicable, special tests shall be performed according to the manufacturer's instructions and all pertinent data shall be recorded in the test report.

8.4.3.2 Verification of rated current

The test requested in 8.4.3.2 of IEC 60269-1 is replaced by the following.

Three samples are to undergo 3000 repetitions of current cycling where one cycle is represented in Figure 101. None of the samples shall exhibit cracking or crazing of the fuse body.

After this test, the resistance of the fuse-link at room temperature shall not have changed by more than 10 %, and tests presented in 8.11.2.4 and Tables 102 and 103 shall be made.

8.4.3.5 Conventional cable overload protection test

Not applicable.

8.4.3.6 Operation of indicating devices and strikers, if any

The correct operation of indicating devices is verified in combination with the verification of breaking capacity (see 8.5.5).

For verifying the operation of strikers, if any, an additional test sample shall be tested:

– at a current of I_5 (see Table 104);

– at a recovery voltage of 50 V.

The value of the recovery voltage may be exceeded by 10 %.

The striker shall operate during all tests.

8.5 Verification of the breaking capacity

8.5.1 Arrangement of the fuse

In addition to the conditions of 8.1.4 and 8.3.1, the following requirement applies.

For breaking-capacity tests, the fuse-link shall be mounted and connected the same way as it would be in service.

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8.5.5 Test method

8.5.5.1 In order to verify that the fuse-link satisfies the conditions of 7.5, tests number – 1, 2 and 5 – shall be made. The number of fuse-links requested in Table 102 shall be tested with the values stated in Table 104.

Test nos. 1 and 2 : If, during test no. 1, the requirements of test no. 2 are met, then this test need not be repeated as test no. 2.

Test nos. 5 – The value of test current is specified in Table 104.

8.5.5.2 For the tests the recovery voltage shall be maintained at a value of 100^{+5}_{0} % of the rated voltage for at least:

– 30 s after operation of fuse-links not containing organic materials in their body or filler;
– 5 min after operation of the fuse-links in all other cases, switching over to another source of supply being permitted after 15 s if the switching time (interval without voltage) does not exceed 0,1 s.

In a lapse of time of at least 6 min and maximum 10 min after the operation, the resistance between the contacts of the fuse-link shall be measured (see 8.5.8 of IEC 60269-1) and noted. With the manufacturer's consent, shorter times are possible if the fuse-link does not contain organic materials in its body or filler.

8.5.8 Acceptability of test results

Fuse-links shall be deemed not to comply with this standard if, during the tests, one or more of the following failures occur:

– ignition of the fuse-link, excluding any paper labels or the like used as indicating devices;
– mechanical damage to the test arrangement;
– mechanical damage to the fuse-link;

NOTE Thermal cracking which leaves the fuse-link in one piece is accepted.

– burning or melting of end caps;
– significant movement of end caps.

Table 104 – Values for breaking-capacity tests on "gPV" fuse-links

	Tests according to 8.5.5.1		
	No. 1	No. 2	No. 5
Mean value of recovery voltage[a]	100^{+5}_{0} % of the rated voltage[b]		
Prospective test current	I_1	I_2	$I_5 = 2\ I_n$
Tolerance on current	$^{+10}_{0}$ %	Not applicable	$^{+20}_{0}$ %
Time constant[c]	1 ms to 3 ms		Inductance ≥ 100 micro Henry

I_1 current which is used in the designation of the rated breaking capacity (see 5.7).

I_2 current which shall be chosen in such a manner that the test is made under conditions which approximate those giving maximum arc energy.

NOTE This condition may be deemed to be satisfied if the current, at the beginning of arcing, has reached a value between 0,5 and 0,8 times the prospective current.

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I_5	test current deemed to verify that the fuse is able to operate satisfactorily in the range of small over-currents.
a	This tolerance includes ripple.
b	The upper limit may be exceeded with the manufacturer's consent.
c	In some practical applications, time-constant values may be found which are shorter than those indicated in the tests and which may result in a more favourable fuse performance.

8.11 Mechanical and miscellaneous tests

8.11.2.4 Verification of freedom from unacceptable levels of thermally induced drift

Nine samples of each fuse-link having the largest rated current and five samples of each fuse-link having the smallest rated current are each to be subjected to temperature cycling consisting of 50 cycles of heating and cooling. Each cycle consisting of 15 min with the fuse-link body maintained at -40 ± 5 °C followed by 15 min with the fuse-link body maintained at 90 ± 5 °C (any convenient ramp rate). At the conclusion of the 50 cycles, the samples shall be returned to room temperature (25 ± 5 °C) for a minimum of 3 h.

At the conclusion of the temperature cycling, the samples of the fuse-link having the largest rated current are to be subjected to the tests described as follows:

8.4.3.1	Conventional non-fusing current (I_{nf})
	Conventional fusing current (I_f)
8.5	No.1 Breaking capacity and operating characteristics (Table 104)
	No.2 Breaking capacity and operating characteristics (Table 104)
	No.5 Breaking capacity and operating characteristics (Table 104)

At the conclusion of the temperature cycling, the samples of the fuse-link having the smallest rated current are to be subjected to the tests described as follow:

8.4.3.1	Conventional non-fusing current (I_{nf})
	Conventional fusing current (I_f)
8.5	No. 1 Breaking capacity and operating characteristics (Table 104)

See tables 102 and 103.

8.11.2.5 Verification of functionality at temperature extremes

a) One sample of each fuse-link having the largest rated current and one sample of each fuse-link having the smallest rated current shall be subjected to a temperature of 50 ± 5 °C for a period of 3 h or until temperatures stabilize. Each fuse-link shall be subjected to its rated current (In) for a time equal to the conventional time specified in Table 101. It shall not operate during this time.

b) One sample of each fuse-link having the largest rated current and one sample of each fuse-link having the smallest rated current shall be subjected to a temperature of 50 ± 5 °C for a period of 3 h or until temperatures stabilize. Each fuse-link shall be subjected to its conventional fusing current (If). It shall operate within the conventional time as specified in Table 101. The fuse link shall operate without external effects or damage.

See Tables 102 and 103.

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