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IS 9385-1 (1979): High voltage fuses, Part 1: Current limiting fuses [ETD 39: Fuses]



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*Indian Standard*  
SPECIFICATION FOR  
HIGH VOLTAGE FUSES  
**PART I CURRENT LIMITING FUSES**

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BUREAU OF INDIAN STANDARDS  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

# Indian Standard

## SPECIFICATION FOR HIGH VOLTAGE FUSES

### PART I CURRENT LIMITING FUSES

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# IS : 9385 ( Part I ) - 1979

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# *Indian Standard*

## SPECIFICATION FOR HIGH VOLTAGE FUSES

### PART I CURRENT LIMITING FUSES

#### 0. FOREWORD

**0.1** This Indian Standard ( Part I ) was adopted by the Indian Standards Institution on 26 December 1979, after the draft finalized by the High Voltage Switchgear and Controlgear Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** Three classes of high voltage fuses are in general use, namely, the expulsion, liquid and high rupturing capacity cartridge types. The most common application is on distribution systems up to 33 kV, while the liquid and cartridge type fuses are available for use on systems up to 132 kV, used largely for protecting voltage transformers.

**0.3** Requirements and tests for high voltage expulsion fuses and similar fuses are covered in IS : 5792-1970\*. This specification is now being brought up to date as to form a part of the present series of specifications on high voltage fuses. Subsequent parts of this specification, hence would cover:

Part II Expulsion fuses and similar fuses

Part III Application guides for high voltage current limiting fuses, expulsion fuses and similar fuses

It is also intended to bring out a standard guide for the determination of short-circuit power factor for testing high voltage fuses.

**0.4** As compared to earlier practices, this standard specifies two levels ( Level 1 and Level 2 ) of severity of impulse withstand voltages. Specific guidelines on the applicability and choice of these values are provided in Part III of this standard.

**0.5** In the preparation of this standard ( Part I ), considerable assistance has been derived from IEC Pub 282- 1 ( 1974 ) 'High voltage fuses: Part 1 Current limiting fuses' published by the International Electrotechnical Commission.

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\*Specification for high voltage expulsion fuses and similar fuses.

**0.6** In order to facilitate comparison with the international standards and for ease of reference, the Committee has decided to add in the form of an appendix, the major differences between this Indian Standard and the corresponding IEC Publication(s) ( *see* Appendix A ).

**0.7** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960\* The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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## 1. SCOPE

**1.1** This standard ( Part I ) applies to all types of high-voltage current-limiting fuses designed for use outdoors or indoors on alternating current systems of 50 Hz and of rated voltages exceeding 1 000 V.

**1.2** 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 device of the switching device for which separate or additional requirements have to be complied with is outside the scope of this standard.

**NOTE** — This standard refers primarily to three-phase systems with earthed neutral. For applications on single-phase systems or three-phase systems with unearthed neutral, *see* Part III of this standard.

**1.3** Fuses designed for the protection of single capacitor units within multi-unit capacitor banks may have to conform to additional requirements other than those specified in this standard.

**1.4** Fuses complying with the standard are to be operated under the normal conditions of service as detailed in Appendix B.

## 2. TERMINOLOGY

**2.0** For the purpose of this standard, the following definitions in addition to those given in IS : 1885 ( Part XVII )-1969†, shall apply.

### 2.1 Electrical Characteristics

**2.1.1 Rating** — General term employed to designate the characteristic values that together define the working conditions upon which the tests are based and for which the equipment is designed.

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

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\*Rules for rounding off numerical values ( *revised* ).

†Electrotechnical vocabulary : Part XVII Switchgear and controlgear.



**2.1.2 Prospective Current ( of a Circuit and with Respect to a Fuse )** — The current that would flow in the circuit, if the fuse was replaced by a conductor of negligible impedance.

NOTE — For the method to evaluate and express the prospective current, see 6.5.2.1 and 6.5.2.2.

**2.1.3 Prospective Breaking Current** — The prospective current evaluated at a time corresponding to the instant of the initiation of the arc in a fuse during a breaking operation.

Conventions relating to the instant of the initiation of the arc are given in 6.5.2.3.

**2.1.4 Cut-Off Current ( of a Fuse )** — The 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.

**2.1.5 Breaking Capacity** — A value of prospective breaking current that a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour.

**2.1.6 Pre-arcing Time ( Melting Time )** — The time between the commencement of a current large enough to cause a break in the fuse-element(s) and the instant when an arc is initiated.

**2.1.7 Arcing Time** — The interval of time between the instant of the initiation of the arc and the instant of final arc extinction.

**2.1.8 Operating Time ( Total Clearing Time )** — The sum of the pre-arcing time and the arcing time.

**2.1.9 Joule Integral (  $I^2 t$  )** — The integral of the square of the current

over a given time interval:  $I^2 t = \int_{t_0}^{t_1} (i^2) dt.$

NOTE 1 — When considered from the point of view of the circuit protected by a fuse, the value of the Joule integral over the operating time of the fuse is referred to a specific energy, that is, the energy released as heat in  $1 \Omega$  of circuit resistance.

NOTE 2 — The values of the Joule integral usually stated for fuse-links are pre-arcing Joule integral and operating Joule integral extended over the pre-arcing time and the operating time respectively.

**2.1.10 Virtual Time** — The value of the 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.

**2.1.11 Time/Current Characteristics** — A curve giving the virtual time as a function of the rms value of the symmetrical component of the prospective current under stated conditions of operation.

NOTE — Time/current characteristics usually stated for a fuse-link are referred to the pre-arcing time and the operating time.

**2.1.12 Cut-Off Characteristics** — A curve giving the value of the cut-off current as a function of the value of the prospective current under stated conditions of operation.

NOTE — In the case of ac, the value of the cut-off current is the maximum value which can be reached for any degree of asymmetry of the prospective current. In the case of dc, the value of the cut-off current is the maximum value reached.

**2.1.13 Recovery Voltage** — The 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 recovery voltage (see 2.1.13.2) alone exists.

**2.1.13.1 Transient recovery voltage (restriking voltage) (abbreviated TRV)** — The recovery voltage during the time in which it has a significant transient character.

NOTE 1 — The transient 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 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.

**2.1.13.2 Power frequency recovery voltage (or steady state recovery voltage)** — The recovery voltage after the transient voltage phenomena have subsided.

NOTE — In the case of dc, the steady state recovery voltage is expressed by the mean value where ripple is present.

**2.1.13.3 Prospective transient recovery voltage (of a circuit)** — The transient recovery voltage following the breaking of a prospective current without any direct component 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, that is, having instantaneous transition from zero to infinite impedance at the very instant of zero current (that is, at the "natural" current 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.

**2.1.14 Switching Voltage** — The maximum instantaneous value of voltage which appears across the terminals of a fuse during its operation.

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

**2.1.15 Minimum Breaking Current** — A minimum value of prospective current that a fuse-link is capable of breaking at a stated voltage under prescribed conditions of use and behaviour.

**2.1.16 Power Dissipation ( of a Fuse-Link )** — The power released in a fuse-link carrying a stated value of current under prescribed conditions of use and behaviour.

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

## 2.2 Fuses and Their Component Parts ( see Fig. 1 )

**2.2.1 Fuse** — A switching device that, by the fusion of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted and breaks the current when it exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete switching device.

**2.2.2 Terminal** — A conducting part of a fuse provided for an electric connection to external circuits.

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

**2.2.3 Fuse-Base ( Fuse-Mount )** — The fixed part of a fuse provided with terminals for connection to the external circuit. The fuse-base comprises all the parts necessary for insulation.

**2.2.4 Fuse-Base Contact ( Fuse-Mount Contact )** — A conducting part of a fuse-base, connected to a terminal and intended to engage with a fuse-carrier contact or with a fuse-link contact.

**2.2.5 Fuse-Carrier** — The movable part of a fuse designed to carry the fuse-link. The fuse-carrier does not include the fuse-link.

**2.2.6 Fuse-Carrier Contact** — A conducting part of a fuse-carrier connected to a fuse-link contact and intended to engage with a fuse-base contact.

**2.2.7 Fuse-Link ( Fuse-Unit )** — A part of a fuse including the fuse-element(s) which requires replacement by a new fuse-link after the fuse has operated and before the fuse is put back into service.

**2.2.8 Fuse-Link Contact** — A conducting part of a fuse-link intended to engage with a fuse-base contact or with a fuse-carrier contact.

**2.2.9 Fuse-Element** — A part of a fuse designed to melt when the fuse operates.

**2.2.10 Indicating Device ( Indicator )** — A device which is provided to indicate at the fuse whether the fuse has operated.

**2.2.11 Striker** — A mechanical device which is a part of a fuse and which operates during the fuse-operation satisfying specified requirements with respect to its force and travel.

**NOTE** — A striker may be used for the purpose of signalling, indicating and/or tripping other apparatus.

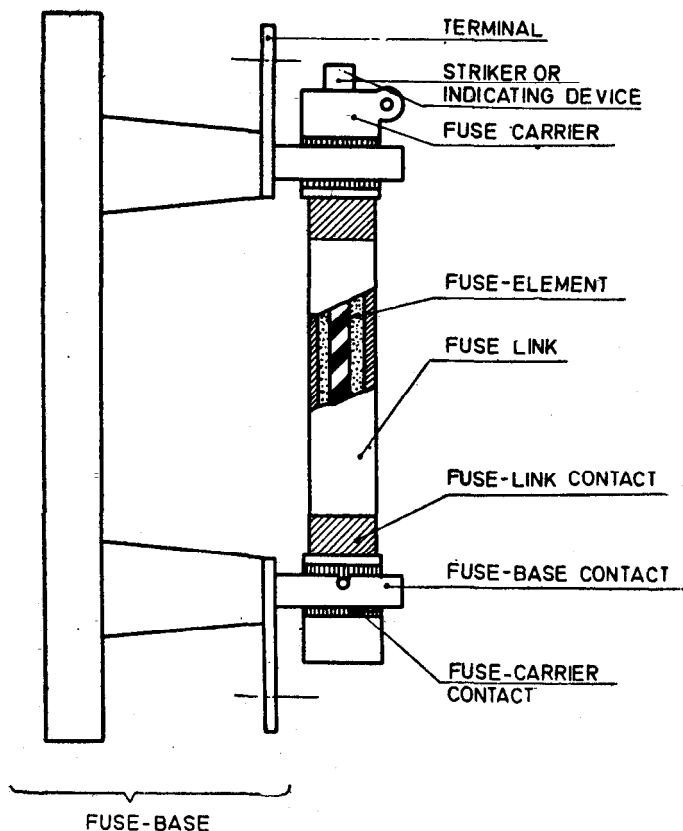


FIG. 1 TERMINOLOGY

## 2.3 Additional Terms

**2.3.1 Current-Limiting Fuse-Link** — A fuse-link that, during and by its operation in a specified current range, limits the current to a substantially lower value than the peak value of the prospective current.

**2.3.2 Isolating Distance (for a Fuse)** — The shortest distance between the fuse-base contacts or any conducting parts connected thereto, measured on a fuse with the fuse-link or fuse-carrier removed.

**2.3.3 Homogeneous Series (of Fuse-Links)** — A series of fuse-links, deviating from each other only in such characteristics that, for a given test, the testing of one or a reduced number of particular fuse-link(s) of the series may be taken as representative of all the fuse-links of the series (see 6.5.3.1).

### 3. RATINGS AND CHARACTERISTICS

#### 3.0 List of Ratings and Characteristics

##### 3.0.1 Ratings

###### a) Ratings of the fuse-base

- 1) Rated voltage ( 3.1 );
- 2) Rated current ( 3.2 );
- 3) Rated insulation level ( power-frequency, dry, wet and impulse withstand voltages ) ( 3.6 ).

###### b) Ratings of the fuse-link

- 1) Rated voltage ( 3.1 ),
- 2) Rated current ( 3.2 ),
- 3) Rated breaking current ( 3.3 ),
- 4) Rated frequency ( 3.4 ),
- 5) Rated minimum breaking current for back-up fuses ( 3.5 ),
- 6) Rated TRV ( 3.11 ).

##### 3.0.2 Characteristics

###### a) Characteristics of the fuse

- 1) Temperature-rise limits ( 3.7 ).

###### b) Characteristics of the fuse-link

- 1) Class ( 3.5 ),
- 2) Switching voltages ( 3.8 ),
- 3) Time/current characteristics ( 3.9 ),
- 4) Cut-off characteristics ( 3.10 ),
- 5) Characteristics of the strikers ( 3.12 ).

**3.1 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.

**3.1.1** The rated voltage shall be selected from the values given below:

3.6, 7.2, 12, 24, 36, 72.5 and 145 kV.

These correspond to highest system voltage.

**3.2 Rated Current of the Fuse-Base** — The current assigned to the fuse-base that a clean new 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.

**3.2.1** The rated current of the fuse-base shall be selected from the following values:

10, 25, 63, 100, 200, 400, 630 A.

**3.3 Rated Current in Amperes and Rated Breaking Current of the Fuse-Link in Kiloamperes** — 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 temperature of not more than 40°C.

The rated breaking current is the value of the breaking capacity specified for a fuse.

**3.3.1** The rated current and the rated breaking current 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 ( *see IS : 1076-1967\** ).

**3.4 Rated Frequency** — The frequency for which the fuse has been designed and to which the values of the other characteristics correspond. Standard value of rated frequency is 50 Hz.

### **3.5 Minimum Breaking Current and Class**

**3.5.1** Two classes of fuses are recognized according to the range in which they can be used, back-up fuses and general purpose fuses ( *see 4.0.1 and 4.0.2* ). In both cases the manufacturer shall indicate the class and for back-up fuses the value of the rated minimum breaking current.

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\*Preferred numbers ( *first revision* ).

**3.6 Rated Insulation Level (of a Fuse-Base)** — The voltage values (both power frequency and impulse) which characterise the insulation of the fuse-base with regard to its capability of withstanding the dielectric stresses.

**3.6.1** The insulation level (power frequency, dry, wet and impulse withstand) voltages shall be selected from Table 1 shown below.

TABLE 1 INSULATION LEVEL VALUES

RATED VOLTAGE OF THE FUSE	RATED LIGHTNING IMPULSE WITHSTAND VOLTAGE ( POSITIVE AND NEGATIVE POLARITY )				RATED 1 MIN POWER FREQUENCY WITHSTAND VOLTAGE ( DRY AND WET )			
	List 1		List 2					
	To earth and between poles	Across the isolating distance of the fuse base ( see notes )	To earth and between poles	Across the isolating distance of the fuse base ( see notes )	To Earth and between Poles	Across the Isolating Distance of the Fuse Base ( see Notes )		
(1)	(2)	(3)	(4)	(5)	(6)	(7)		
kV ( rms )	kV( peak )	kV( peak )	kV( peak )	kV( peak )	kV ( rms )	kV ( rms )		
3.6	20	23	40	46	10	12		
7.2	40	46	60	70	20	23		
12	60	70	75	85	28	32		
24	95	110	125	145	50	60		
36	145	165	170	195	70	80		
72.5	325	375	325	375	140	160		
		Full Insulation			Reduced Insulation	Full In- duc- sula- tion	Re- duc- ed In- sula- tion	Full Re- duc- ed In- sula- tion
145	650	750	550	630	275	230	315	265

NOTE 1 — An isolating insulation level should only be specified for those fuse-bases to which isolating properties are assigned.

NOTE 2 — The values in this table are based on the following standard reference conditions:

Temperature 27°C, pressure 760 mmHg, and humidity 11 g/m<sup>3</sup> of water.

**3.7 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 2.

NOTE — Where engaging contact surfaces having different coatings, the permissible temperatures and temperature-rises shall be as follows:

- For bolted contacts and terminals, those of the component having the higher values permitted in Table 2.
- For spring loaded contacts, those of the component having the lower values permitted in Table 2.

**TABLE 2 LIMITS OF TEMPERATURE AND TEMPERATURE-RISE FOR COMPONENTS AND MATERIALS**

( Clause 3.7 )

COMPONENT OR MATERIAL  (1)	MAXIMUM VALUE OF	
	Temperature	Temperature-Rise
	(2) °C	(3) °C
Copper contacts in air:		
a) Spring loaded contacts:		
— bare	75	35
— silver-coated	105	65
— tin-coated	95	55
— other coatings	See Note 1	
b) Bolted contacts:		
— bare	90	50
— silver or tin-coated	105	65
— other coatings	See Note 1	
Copper contacts in oil:		
— bare	80	40
— silver, tin or nickel-coated	90	50
— other coatings	See Note 1	
Bolted terminals in air:		
— bare	90	50
— silver or tin-coated	105	65
— other coatings	See Note 1	
Metal parts acting as springs	See Note 2	
Insulating materials or metal parts in contact with insulating materials of the following classes: *		
Class A	105	65
E	120	80
B	130	90
F	155	115
H	180	140
C	See Note 3	

NOTE 1 — If the manufacturer uses coatings other than those indicated in Table 3, the properties of those materials shall be taken into consideration.

NOTE 2 — The temperature or the temperature-rise shall not reach such a value that the elasticity of the metal is changed.

NOTE 3 — Limited by the requirement not to cause any damage to surrounding parts.

NOTE 4 — For fuses used in enclosures, see Part III of this standard.

\*Classes according to IS: 1271-1958 'Specification for the classification of materials for the insulation of electrical machinery and apparatus in relation to their thermal stability in service'.



**3.8 Switching Voltages** — On request, the manufacturers shall indicate the maximum value of the switching voltages as determined in the breaking tests ( *see* 6.5 ). The values of switching voltages during operation in test duties 1, 2 and 3 shall not exceed those given in Table 3.

TABLE 3 SWITCHING VOLTAGES

RATED VOLTAGE	SWITCHING VOLTAGE
(1)	(2)
kV	kV ( <i>Max</i> )
3.6	12
7.2	23
12	38
24	75
36	112
72.5	226
145	Under consideration

**3.9 Time/Current Characteristics** — The manufacturer shall make available curves from the data determined by the time/current characteristics type tests specified in 6.6.2.

The time/current characteristics shall be presented with current as abscissa and time as ordinate. Logarithmic scales shall be used on both co-ordinate axes.

The curves shall show:

- a) the relation between the virtual pre-arcing time and the prospective current.
- b) the basis of current, whether mean or minimum. If mean current values are used, the tolerance shall not exceed  $\pm 20$  percent. If minimum values are used, the tolerance shall not exceed  $\pm 50$  percent.
- c) the type and rating of the fuse-link to which the curve data apply.
- d) the time-range as specified in 6.6.2.2. For back-up fuses, a dotted line shall be plotted from minimum breaking current to 600 seconds if the minimum breaking current corresponds to a time less than 600 seconds.

**3.10 Cut-Off Characteristics** — The manufacturer shall indicate the upper limit of the cut-off current corresponding to each value of prospective breaking current up to the rated breaking capacity of the fuse under specified conditions determined as part of the breaking type tests specified in 6.5.

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

**3.11 Rated Transient Recovery Voltage ( Rated TRV )** — The rated transient recovery voltage related to the rated breaking current ( *see* 3.3 ) 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.

**3.11.1 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* Appendix C ).

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.

**3.11.2 Representation of Rated TRV** — The following parameters are used for the representation of the rated TRV ( *see also* Fig. 8 ):

$u_c$  = TRV peak voltage in kV, and

$t_d$  = time in  $\mu$ s 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 co-ordinate  $t'$  ).

**3.11.3 Standard Values of Rated TRV** — Standard values of rated TRV of fuses are given in Table 4.

The values given in the tables are prospective values and taken 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 the manufacturer and the user.

TABLE 4 STANDARD VALUES OF RATED TRV\*

( Clause 3.11.3 )

RATED VOLTAGE*	BASIC PARAMETERS		DERIVED VALUES			
	Peak Voltage	Time Co-ordinate	Time Delay †	Voltage Co-ordinate ‡	Time Co-ordinate §	Rate of Rise
$U_r$	$u_0$	$t_3$	$t_d$	$u'$	$t'$	$u_0/t_3$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
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
24	41	88	13.2	13.8	42.5	0.47
36	62	108	16.2	20.6	52	0.57
72.5	124	168	8.4	41.5	64	0.74

\*This table gives representation of TRV by two parameters. For rated voltage 145 kV (in general, for voltages above 72.5 kV) four parameters are used. For values of voltage and time co-ordinates for 145 kV systems, reference shall be made to IS : 2516 (Part I/Sec 3)-1972 'Alternating current circuit-breakers : Part I Requirements, Section 3 Voltages above 11 kV'.

$$u_0 = 1.4 \times 1.5 \times \sqrt{2/3} U_r$$

$$\dagger u' = 1/3 u_0$$

$$\left. \begin{aligned} \dagger t_d &= 0.15 t_3 \\ \S t' &= (0.15 + 1/3) t_3 \end{aligned} \right\} \text{ for } U_r < 72.5 \text{ kV}$$

$$\left. \begin{aligned} \dagger t_d &= 0.05 t_3 \\ \S t' &= (0.05 + 1/3) t_3 \end{aligned} \right\} \text{ for } U_r \geq 72.5 \text{ kV}$$

The rated transient recovery voltage corresponding to the rated breaking current is used for testing at breaking currents equal to the rated value with the permitted deviation given in 6.5.1.2(a). For testing at breaking current less than the rated value, other values of transient recovery voltage are specified [ see 6.5.1.2(b) ].

**3.12 Characteristics of Strikers**—The strikers shall have the characteristics according to the three types given in Table 5.

Strikers of fuse-links are operated by either a charged spring or an explosive charge.

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 specified points on 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 when a static external force is applied.

TABLE 5 CHARACTERISTICS OF STRIKERS

( Clauses 3.12, A-0 and E-3.1 )

TYPE	ENERGY		FREE TRAVEL	FURTHER TRAVEL DURING WHICH ENERGY MUST BE DELIVERED	ACTUAL TRAVEL		MINIMUM WITHSTAND FORCE
	Min	Max			Min	Max	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	J	J	mm	mm	mm	mm	N
Light	0.05	0.5	2	8	10	20	Not applicable
Medium	0.5	1.5	4	16	20	40	20
Heavy	0.5	3	4	6	10	16	40

#### 4. STANDARD CONDITIONS OF USE AND BEHAVIOUR

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

- back-up fuses, and
- general-purpose fuses.

**4.0.1 Back-Up Fuse** — A current-limiting fuse capable of breaking, under specified conditions of use and behaviour, all currents from the rated breaking current down to the rated minimum breaking current.

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

**4.0.2 General Purpose Fuse** — A current-limiting fuse capable of breaking, under specified conditions of use and behaviour, all currents from the rated breaking current down to the current that causes melting of the fuse-element in 1 hour.

#### 4.1 Breaking Characteristics

**4.1.1 General** — When used in systems with service voltages less than the rated voltage of the fuse, the breaking capacity in kiloamperes is not less than the rated 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 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 Part III of this standard ).

**4.1.2 Standard Conditions of Use with Respect to Breaking Capacity—** Fuses shall be capable of breaking correctly any value of prospective current, irrespective of the possible dc component, provided that:

- a) the ac component is not lower than the minimum breaking current and not higher than the rated breaking current;
- b) the power-frequency recovery voltage is not higher than that specified in 6.5.2.4 ( for special conditions, see Part III of this standard );
- c) the prospective transient recovery voltage is within the limits represented by the tests specified in 6.5.1.2;
- d) the frequency is between 48 Hz and 52 Hz;
- e) the power factor is not lower than that represented by the tests specified in 6.5.2.4; and
- f) 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 6.5.1.2.

NOTE — As regards the prospective TRV characteristics, the time co-ordinate  $t_0$  is not significant for the behaviour of fuses ( except for those fuses, which cause high arc voltage peaks immediately after arc initiations, see 6.5.1.2 ).

**4.1.3 Standard Conditions of Behaviour with Respect to Breaking Capacity—** According to the conditions of use indicated in 4.1.2, 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.

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

- c) when fuse-links are provided with indicating devices or strikers:
  - 1) indicating devices need not comply with specific requirements, but shall visually and fully operate; and
  - 2) strikers shall comply fully with the requirements specified in 3.12.

- d) Operation shall not generate switching voltages higher than the values specified in 3.8.
- e) The values of cut-off current corresponding to each value of prospective breaking current shall not exceed the values corresponding to the cut-off characteristics given by the manufacturer.
- f) After operation, the fuse shall be capable of withstanding the power-frequency recovery voltage across its terminals.

**4.2 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 6.4.1.2.

Unless otherwise specified, the time/current characteristics shall be deemed to apply at an ambient air temperature of 27°C.

## **5. MARKING**

**5.0** The markings which shall be indelibly made 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.

### **5.1 On the Fuse-Base**

- a) Manufacturer's name or trade-mark,
- b) Rated voltage, and
- c) Rated current.

### **5.2 On the Fuse-Link**

- a) Manufacturer's name or trade-mark,
- b) Manufacturer's type designation,
- c) Rated voltage,
- d) Rated current,
- e) Rated breaking current,
- f) Rated minimum breaking current ( for back-up fuses only ), and
- g) Direction of striker ( if fitted ).

**5.3** It shall also be indicated on both fuse-link and fuse-base, when applicable, if they are designed for outdoor service.

## 5.4 Fuses may also be marked with the ISI Certification Mark.

**NOTE** — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution ( Certification Marks ) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

## 6. TESTS

### 6.0 General

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

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

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

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

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

Where tests are made on a fuse whose report of type tests had 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 percent of the specified power-frequency recovery voltage, nevertheless the manufacturer is not liable for any performance figures exceeding 100 percent of the specified power-frequency recovery voltage.

**6.0.3** Special tests meant for certain types of fuses or for fuses for special applications are given in 7.

## 6.1 List of Type Tests

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

- a) Dielectric tests ( 6.3 ),
- b) Temperature-rise tests ( 6.4 ),
- c) Breaking tests ( 6.5 ),
- d) Tests for time/current characteristics ( 6.6 ),
- e) Oil-tightness tests ( only for fuses intended to be used in oil ) ( 6.7 ), and
- f) Test of strikers ( 6.8 ).

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

## 6.2 Common Test Practices for All Type Tests

**6.2.1** The following shall be common test practices, unless otherwise specified:

- a) The device shall be new, clean and in good condition.
- b) The fuse to be tested shall be mounted on a rigid earthed metal structure in the normal service position for which it is designed. The connections shall be so positioned that the normal clearances are not reduced.

## 6.3 Dielectric Tests

### 6.3.1 Test Practices

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

**6.3.1.2 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 substantially a straight line parallel to the fuse-link for an unsupported distance of at least the isolating distance of the fuse.

**6.3.2 Application of Test Voltage for Impulse and Power-Frequency Tests** — The test voltage specified in Table 1 for 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 the terminals and all earthable metal parts:

- 1) with the fuse including the fuse-link and its fuse-carrier completely assembled ready for service, and
- 2) with the fuse-link removed.

NOTE — For multi-pole arrangements of fuses:

- a) between all live parts of all poles connected together and the earthable metal parts, and
- b) between the terminals of each pole and the earthable metal parts with all the live parts of the other poles connected to the earthable metal parts.

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

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

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

**6.3.3 Atmospheric Conditions During Test** — The test shall be made at atmospheric conditions as near as possible to the standard conditions specified in IS : 2071 ( Part I )-1974\*.

The correction factors for density and for air humidity shall be as given in IS : 2071 ( Part I )-1974\* unless otherwise mentioned.

**6.3.4 Test Voltages** — The test voltages to be used for the tests shall be in accordance with those given in Table 1.

**6.3.5 Lightning Impulse Voltage Dry Tests** — Fuses shall be subjected to lightning impulse voltage dry tests with 1·2/50 impulses in accordance with IS : 2071 ( Part I )-1974\*.

Fifteen consecutive impulses at the rated lightning impulse withstand voltages specified in Table 1 shall be applied as follows:

- a) At the rated withstand voltage to earth and between poles for all the test conditions (a) of 6.3.2;
- b) At the rated withstand voltage to earth and between poles for the test condition (b) of 6.3.2, if isolating properties are not assigned to the fuse base; and
- c) At the rated withstand voltage across the isolating distance for the test condition (b) of 6.3.2, if isolating properties are assigned to the fuse-base.

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\*Methods of high voltage testing: Part I General definitions and test requirements (first revision).

## IS : 9385 ( Part I ) - 1979

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

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

**6.3.6 Power-Frequency Voltage Dry Tests** — Fuses shall be subjected to one-minute power-frequency voltage dry tests, as specified in IS : 2071 ( Part I )-1974\*.

The test circuit ( transformer with voltage-regulating device ) shall have a short-circuit current of at least 0.2 A. It is permissible to check the magnitude of the current at approximately one-tenth of the specified voltage.

The values for the rated one-minute power-frequency withstand voltage tests are specified in Table 1. The tests shall be made at the following values.

- a) At the rated withstand voltage to earth and between poles for all the test conditions (a) of 6.3.2;
- b) At the rated withstand voltage to earth and between poles for the test condition (b) of 6.3.2, if isolating properties are not assigned to the fuse-base; and
- c) At the rated withstand voltage across the isolating distance for the test condition (b) of 6.3.2, if isolating properties are assigned to the fuse-base.

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

**6.3.7 Power-Frequency Wet Tests** — Outdoor type fuses shall be subjected to power-frequency voltage wet tests under the same conditions as specified in 6.3.6 except for the duration, which is 1 minute. However, if a disruptive discharge on external self-restoring insulation occurs, this test shall be repeated with the same test conditions and the fuse shall be considered to have passed this test successfully if no further disruptive discharge occurs.

During these tests, the fuses shall be subjected to artificial rain at an angle of 45° to the vertical, the test procedure being in accordance with IS : 2071 ( Part I )-1974\*.

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\*Methods of high voltage testing : Part I General definitions and test requirements ( *first revision* ).

## 6.4 Temperature-Rise Tests

**6.4.1 Test Practices** — Temperature-rise tests shall be on one fuse and as given below.

**6.4.1.1 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.

**6.4.1.2 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 shall be mounted in the most unfavourable position within the directions specified by the manufacturer and connected to the test circuit by bare copper conductors as follows: each conductor shall be approximately 1 m long, mounted in a plane parallel to the mounting surface of the fuse, but they may be in any direction in this plane. The sizes of the leads are given in Table 6.

NOTE — Depending on the value of the test currents, aluminium conductors of approximate sizes, in the place of bare copper conductors can also be used for the purposes of temperature-rise tests. For details of standard cross-sections of aluminium conductors see Tables 6 and 7 of IS : 9224 ( Part I )-1979\*.

**TABLE 6 SIZES OF BARE COPPER CONDUCTORS FOR THE PURPOSES OF TEMPERATURE-RISE TESTS**

CURRENT RATING OF THE FUSE	SIZE OF BARE COPPER CONDUCTORS
(1)	(2)
A	mm <sup>2</sup>
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 400 to 600

NOTE — The equivalent area in MCM (one thousand circular mils) can be obtained by multiplying the above numbers in col (2) by 2.

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 52 Hz. Each test shall be made over a period of time sufficient for the temperature-rise to reach a constant value

\*Specification for low voltage fuses: Part I General requirements.

(for practical purposes, this condition is regarded as being obtained when the variation does not exceed  $1^{\circ}\text{C}$  per hour).

The temperature-rise of the various parts of the fuse shall not exceed the specified values at an ambient air temperature not more than  $40^{\circ}\text{C}$  during the test. No correction shall be applied to any ambient air temperature within the range of 10 to  $40^{\circ}\text{C}$ .

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

**6.4.2.1 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 bulbs of thermometers shall be suitably protected against cooling from the outside. The protected area shall be negligible compared with the cooling area of the part to which the thermometer is secured.

**6.4.2.2 Ambient air temperature** — The ambient air temperature is the average temperature of the air surrounding the fuse or its elements. It shall be measured during the last quarter of the test period by means of thermocouples or thermometers at a distance of approximately 1 m from the fuse. It is permissible to use an additional fuse of the same construction as the fuse under test or an oil cup or any other suitable means for the determination of ambient air temperature.

## 6.5 Breaking Tests ( see Fig. 2 )

### 6.5.1 Test Practices

**6.5.1.1 Description of tests to be made** — Tests shall be made according to the instructions given in Table 7 and shall include three test duties:

Test duty 1: Verification of the rated breaking current  $I_1$  ( see Notes 1, 3, 4 and 5 )

Test duty 2: Verification of operation with prospective currents  $I_2$  near to those giving the maximum arc energy ( see Notes 1 to 4 )

Test duty 3: Verification of operation with the current  $I_3$ ; for general purpose fuses, this is the current that causes melting in 1 hour; for back-up fuses, it is the minimum breaking current ( see Note 1 ).

It is not necessary to make breaking tests on fuse-links of all current ratings of a homogeneous series ( see 6.5.3 for the requirements to be met and tests to be made ).

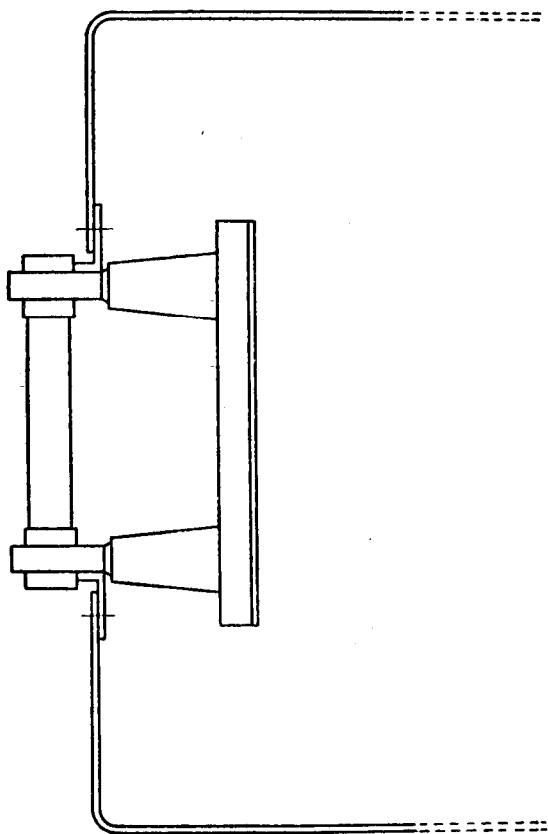


FIG. 2 BREAKING TESTS — ARRANGEMENT OF THE EQUIPMENT

Also an homogeneous series can be approved without breaking tests by interpolation between the results of tests of related homogeneous series of fuses of higher and lower rated voltages; *see* 6.5.4 for the requirements to be met.

NOTE 1 — Values of  $I_1$ ,  $I_2$  and  $I_3$  are the rms values of the ac component of the current.

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

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

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

where

$I_a$  = prospective current for test duty 2;

$i_1$  = instantaneous current at instant of melting in test duty 1;

$I_1$  = 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 6.6 and 3.9 ). If a time/current characteristic curve exists for virtual times less than one-half-cycle, it is preferable to use the current corresponding on this time/current characteristic to a time of 0.08 normal half-cycles.

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

NOTE 4 — If the prospective current necessary to comply with the requirements of test duty 2 is greater than the rated breaking current, test duties 1 and 2 shall be replaced by six tests at rated breaking current with making angles as nearly as possible equally distributed with approximately 30° between each. (For parameters of test duty 2, see Table 7 except making angle and value of instantaneous current at initiation of arcing.)

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

**6.5.1.2 Characteristics of the test circuit** — The breaking tests shall be made with single-phase alternating current and with single fuses.

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

The test circuit frequency shall be between 45 Hz and 52 Hz.

It is recommended that there shall be no distortion of the power-frequency recovery voltage that can readily be seen by inspection of the oscillogram. Where some distortion is unavoidable, it shall not be such as to necessitate the open-circuit voltage to be more than 107 percent of the voltage corresponding to the required recovery voltage on test duties 1 and 2, as specified in 6.5.1.1.

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

Switching-voltage protective equipment used in the test circuit shall be such that no sparkover 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 6.0.1, para 3).

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

These requirements are illustrated in Fig. 9.

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

**a) Test duty 1**

In principle, the tests are to be made with the standardized values of TRV specified in 3.11.3. However, as stated in Appendix D current-limiting fuses are not sensitive to TRV characteristics, except when the highest arc voltage is reached immediately after initiation of the arc. Consequently, for convenience of testing, the tests may be made as follows:

A first test will be made with any convenient prospective TRV and with initiation of arcing from 65° to 90° after voltage zero. If during this test, the highest peak of arc voltage is not reached within a time equal to  $2 t_3$  after initiation of arcing, this test is valid and the test duty 1 will be completed in the same circuit. Otherwise, the circuit shall be changed to provide a TRV with an envelope being at no time below the reference line specified in 3.11.3 and an initial portion not crossing the specified delay line. All the tests of test duty 1 shall be made in this new circuit.

**b) Test duty 2**

Tests shall be made with the values of prospective TRV specified in Table 6A.

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

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

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

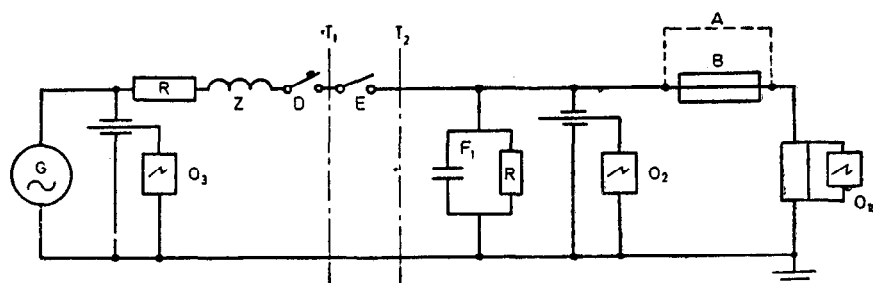


FIG. 3 BREAKING TESTS — TYPICAL CIRCUIT DIAGRAM FOR TEST DUTIES 1 AND 2

c) Test duty 3

TRV characteristics are not specified for this test duty; 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 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.

TABLE 6A VALUES OF PROSPECTIVE TRV

[ Clause 6.5.1.2(b) ]

RATED VOLTAGE	BASIC PARAMETERS		RATE OF RISE
	Peak Voltage	Time Co-ordinate	
$U_r$	$u_0$	$t_3$	$u_0/t_3$
(1)	(2)	(3)	(4)
kV	kV	$\mu s$	kV/ $\mu s$
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
24	44	264-352	0.167-0.125
36	66	324-432	0.203-0.152
72.5	133	504-672	0.265-0.199

$$u_0 = 1.5 \times 1.5 \times \sqrt{2/3} U_r$$

Critical damping is obtained when

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



where

$f_0$  = natural frequency of the circuit without additional damping,

$f_N$  = power frequency, and

$X$  = reactance of the circuit at power frequency.

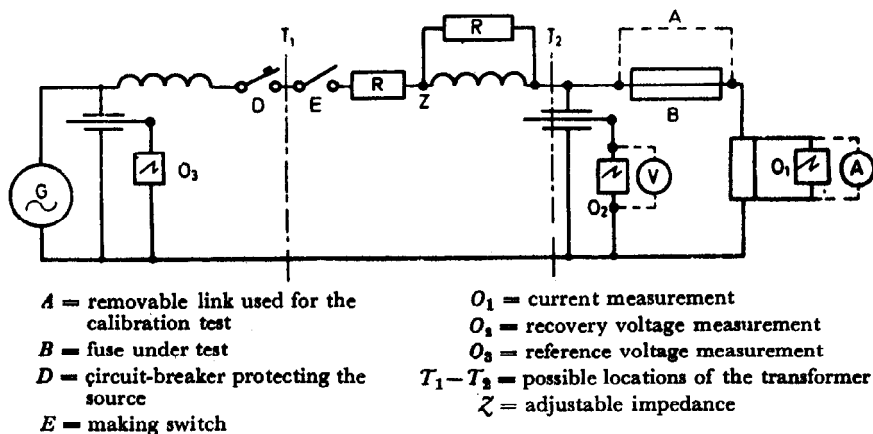


FIG. 4 BREAKING TESTS — TYPICAL CIRCUIT DIAGRAM FOR TEST DUTY 3

**6.5.1.3 Test samples** — The fuse-link shall be tested in a fuse-base as specified by the manufacturer of the fuse-link.

In making tests on renewable fuses, fuse-links or refill units of the same manufacturer as the fuse or as specified by the manufacturer of the fuse shall be used.

**6.5.1.4 Arrangement of the equipment** — For test duties 1 and 2, the conductors shall be arranged as shown in Fig. 2, in order to reproduce the electromagnetic forces which 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 or at 0.50 m if the insulator height does not exceed 0.50 m.

**NOTE 1** — 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.

**NOTE 2** — Oil-tight fuse-links shall be tested in an oil-filled enclosure designed to simulate service conditions.

## 6.5.2 Test Procedure

**6.5.2.1 Calibration of the test circuit** — The fuse or the fuse-link under test shall be replaced by a link of negligible impedance compared with that of the test circuit as shown in Fig. 3 and 4.

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

**6.5.2.2 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 7.

For test duties 1, 2 and 3, 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 oscillographic record.

After the fuse has operated, recovery voltage shall be maintained across the fuse for the periods specified in Table 7. The first few cycles shall be recorded by an oscillograph and the remainder may be observed on a voltmeter.

**NOTE** — During this period, the power frequency may be lower than the specified minimum value.

**Alternative test method for test duty 3** — To avoid testing at the specified voltage for the full test period, an alternative test may be made as follows:

The fuse to be tested is connected in a low-voltage test circuit for the major portion of the test period and then switched to a high-voltage test circuit for the conclusion of the test.

The test circuits shall be as follows:

- a) Any low voltage 50 Hz power source sufficient to cause the desired current to flow through the fuse to be tested and means for adjusting the circuit to hold the current constant.
- b) A high voltage 50 Hz test circuit as indicated in 6.5.1.2. This circuit shall be preadjusted to provide the same current as for the low voltage portion of the test, as well as the parameters as specified in Table 7.
- c) Provision for switching from the low voltage source to the high voltage source such that the current is interrupted for a time interval not longer than 0.2 second; however, the time interval between the reapplication of current and the beginning of arcing shall be long enough to make it possible to have no asymmetry, to evaluate the current and to see from the oscillogram that there is no appreciable decrement of the value of current.

TABLE 7 PARAMETERS FOR BREAKING TESTS

( Clauses 6.5.1.1 and 6.5.2.2 )

PARAMETERS		TEST DUTIES		
		1	2	3
Power-frequency voltage	recovery	( 0.87 × rated voltage )	+5 0 percent	Rated voltage +5. 0-percent
Prospective TRV characteristics	charac-	←— see 6.5.1.2 —→		Not specified
Power factor		←— From 0.07 to 0.15 —→ see Note 1		0.4 to 0.6
Prospective current ( rms value of the ac component )		$I_1$ +5 0 percent	$I_2$	$I_3$ — 0 10 percent see Note 2
Instantaneous current at initiation of arcing	at	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	after	For one test: From 40 to 65° For two tests: From 65 to 90° see Note 3	Not applicable	Not applicable
Maintained voltage after breaking ( see Notes 4 and 5 )		Not less than 15 seconds	Not less than 60 seconds	
Number of tests		3	3	2

NOTE 1 — When the manufacturer agrees, the lower limit does not apply.

NOTE 2 — 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 percent of the total melting time, provided that the current at the initiation of arcing is within the tolerance specified for test duty 3.

NOTE 3 — 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 recognized that these conditions will be practically obtained at least once, when making the three tests indicated.

NOTE 4 — For fuses which are subject in service to the recovery voltage for a time less than 1 second, the maintained voltage period after operation will be 1 second.

NOTE 5 — The initial value of the power-frequency recovery voltage shall be equal to the specified value, but when testing limitations prevent the maintenance of constant voltage, the maintained voltage may drop to 15 percent below the specified value.

**6.5.2.3 Interpretation of oscillograms** — For test duties 1 and 2, the prospective breaking current shall be the rms value of the ac component of the current, measured one half-cycle after the initiation of short circuit in the calibration test ( *see* Fig. 5 and 6 ).

For test duty 3, the breaking current shall be the rms symmetrical current measured at the instant of the initiation of the arc in the breaking test ( *see* Fig. 7 ) or the value indicated by the ammeter.

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* Fig. 5, 6 and 7 ).

**6.5.2.4 Parameters to be used for tests** — The parameters to be used when making the tests are given in Table 7.

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

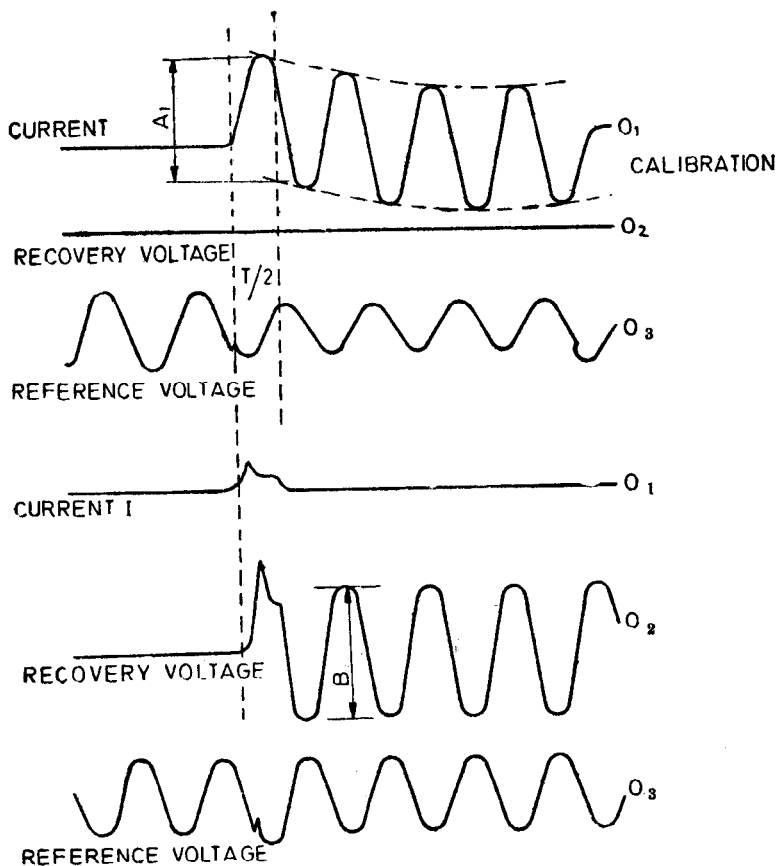
### **6.5.3 Breaking Tests for Fuse-Links of a Homogeneous Series**

**6.5.3.1 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, breaking current and frequency shall be the same.
- b) All materials shall be the same.
- c) All dimensions of the fuse-link except the cross-section and the number of fuse-element(s) as detailed below from item (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 monotonous\* 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 that in distance, if any, between fuse-element(s) and fuse-barrel shall be monotonous\* with respect to the rated current.
- h) A special fuse-element used for an indicator or striker is exempt from (e) and (f) above, but this element shall be the same for all the fuse-links.

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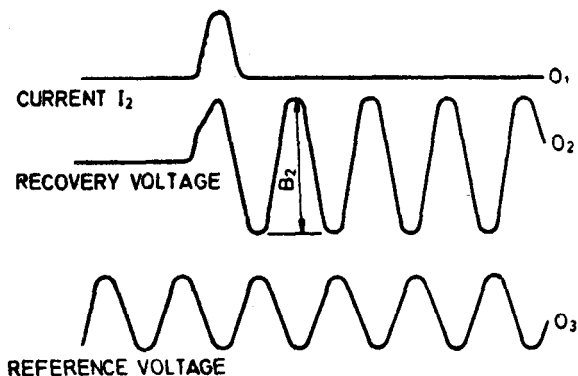
\*Monotonous function: a function continually varying in the same direction for a given direction of the variable.



rms value of the ac component of prospective breaking current  $I_1 = \frac{A_1}{2\sqrt{2}}$

Recovery voltage  $V_1 = \frac{B_1}{2\sqrt{2}}$

FIG. 5 BREAKING TEST — INTERPRETATION OF OSCILLOGRAMS FOR TEST DUTY 1

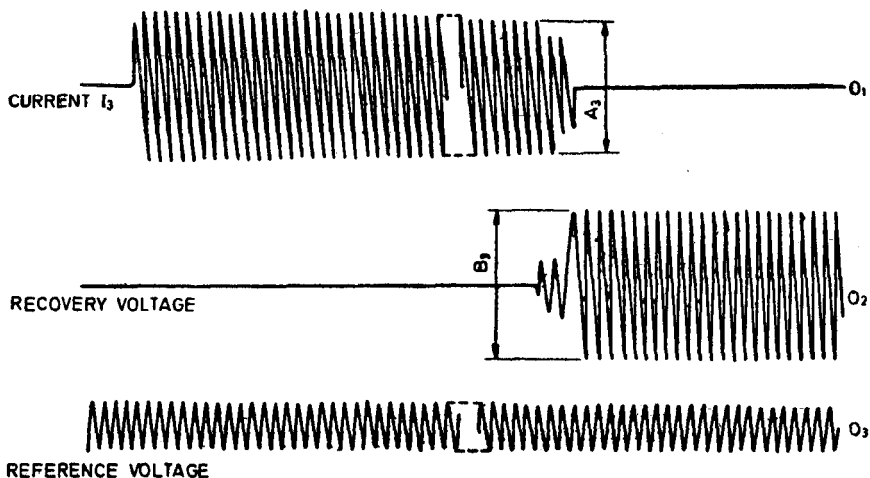


rms value of the ac component of prospective breaking current  $I_2 = \frac{A_2}{2\sqrt{2}}$

$A_2$  is measured from the calibration test as  $A_1$

$$\text{Recovery voltage } V_2 = \frac{B_2}{2\sqrt{2}}$$

FIG. 6 BREAKING TESTS — INTERPRETATION OF OSCILLOGRAMS FOR TEST DUTY 2



rms value of the ac component of breaking current  $I_3 = \frac{A_3}{2\sqrt{2}}$

$$\text{Recovery voltage } V_3 = \frac{B_3}{2\sqrt{2}}$$

FIG. 7 BREAKING TESTS — INTERPRETATION OF OSCILLOGRAMS FOR TEST DUTY 3

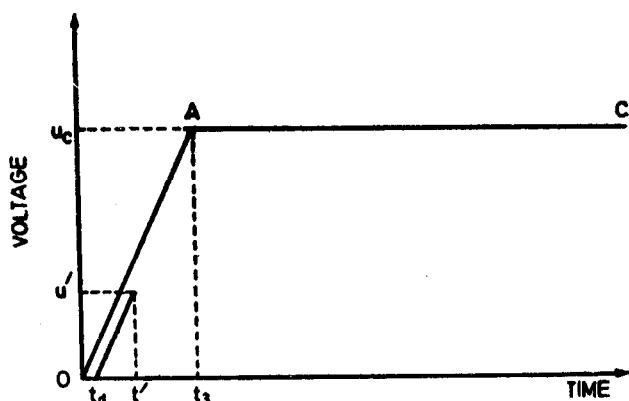


FIG. 8 REPRESENTATION OF SPECIFIED TRV BY A 2-PARAMETER REFERENCE LINE AND A DELAY LINE

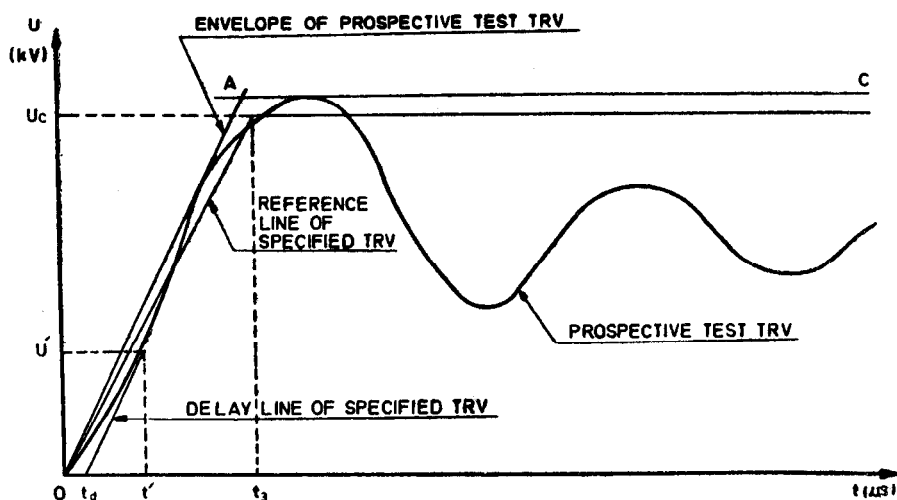


FIG. 9 EXAMPLE OF PROSPECTIVE TEST TRV WITH TWO-PARAMETER ENVELOPE WHICH SATISFIES THE CONDITION TO BE MET DURING TYPE TEST

**6.5.3.2 Test requirements**— In a homogeneous series of fuse-links, breaking tests need only be made in accordance with Table 8.

Symbols in Table 8 are used with the following meanings:

$A$  = fuse-link of lowest current rating,

$B$  = any fuse-link of a current rating between  $A$  and  $C$ , and

$C$  = fuse-link of highest current rating.

The parameters to be considered are:

$S_A, S_B, S_C$ , cross-section of the individual main fuse-elements  $A, B, C$ .

$n_A, n_B, n_C$ , number of main fuse-elements in  $A, B, C$ .

**6.5.3.3 Interpretation of breaking tests**— If the results of tests made according to Table 8 meet the requirements of 4.1.3, any current rating of fuse-links within the homogeneous series shall be deemed to comply with the breaking requirements of this specification.

If a fuse-link does not perform satisfactorily according to 4.1.3 on one or more test series, that fuse-link shall be rejected from the homogeneous series, but such failure does not necessarily entail rejection of any other current rating.

It should be noted that a particular range of current ratings in one barrel size may constitute one homogeneous series for one test duty, but two or more homogeneous series for the purpose of another test duty.

The values of minimum breaking current of fuse-links not tested are determined from test duty 3 as follows:

a) *Constant  $n$ , increase of  $S$ :*

It is assumed that the pre-arcing time at  $I_g$  for fuse-links  $A$  and  $B$  is not less than for the fuse-link  $C$ . The test in accordance with Table 8 is therefore considered as providing that fuse-links  $A$  and  $B$  have a minimum breaking current ascertained by reading from their time/current characteristics the currents corresponding to the pre-arcing time given by the minimum breaking current of fuse-link  $C$  and its time/current characteristic ( see Fig. 10 ).

b) *Constant  $S$ , increase of  $n$ :*

The minimum breaking current  $I_g$  of fuse-links  $A$  and  $C$  may or may not be the same. If they are the same,  $I_g$  is deemed to apply to fuse link  $B$ . If they are different, a straight line is drawn through the points corresponding to the respective minimum breaking currents on the time/current characteristics of fuse-links  $A$  and  $C$ . The intersection of this line and the time/current characteristic of fuse-link  $B$  is deemed to define the minimum breaking current of fuse-link  $B$  ( see Fig. 11 ).



TABLE 8 BREAKING TESTS FOR HOMOGENEOUS SERIES

( Clause 6.5.3.2 )

HOMOGENEOUS SERIES ACHIEVED BY	TEST DUTIES	FUSE-LINKS TO BE TESTED ( Crosses Show the Tests to be Performed )		
		A	B	C
Progressive change in number $n$ and/ or cross section $S$ monotonous with respect to rated current  $n_A < n_B < n_C$  $S_A < S_B < S_C$	1	X		X
	2 see Note 1	X		X
	3 see Note 2	X	X see Note 3	X
Constant number $n$ Increase of cross section $S$  $S_A < S_B < S_C$	1	X		X
	2 see Note 1	X		X
	3			X
Constant cross section $S$ Increase of number $n$  $n_A < n_B < n_C$	1	X		X
	2			X
	3 see Note 2	X		X

NOTE 1 — The test currents  $I_2$  for the fuse-links  $A$  and  $C$  will have been chosen according to the current rating of the fuse-links  $A$  and  $C$  respectively.

NOTE 2 — The fuse-link of lowest current rating shall contain at least 2 individual main fuse-elements in addition to the element, if any, used for operating the striker.

NOTE 3 — This does not require that every rating must be tested, but with diminishing current ratings a test is only to be made for the current rating at which the number of elements is reduced.

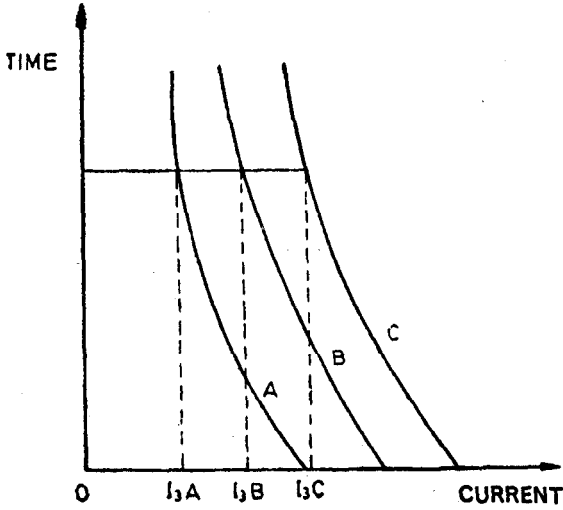


FIG. 10 DETERMINATION OF THE MINIMUM BREAKING CURRENT  
( CONSTANT  $n$ , INCREASE OF  $S$  )

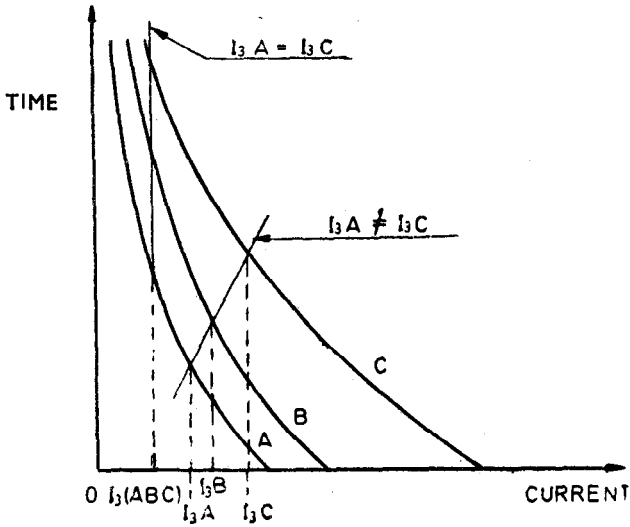


FIG. 11 DETERMINATION OF THE MINIMUM BREAKING CURRENT  
( CONSTANT  $S$ , INCREASE OF  $n$  )

If the manufacturer claims a value of minimum breaking current less than that derived from (a) and (b) above, this shall be proved by a separate test.

**6.5.4 Acceptance of a Homogeneous Series of Fuse-Links by Interpolation** — If two homogeneous series  $X$  and  $Z$  of different voltage ratings  $U_X$  and  $U_Z$  have been tested successfully, a third homogeneous series  $Y$  of an intermediate voltage rating  $U_Y$  need not, in principle, be tested provided that:

- a) The rated voltage  $U_Z$  is not greater than  $2 U_X$ .
- b) The current ratings of  $Y$  are not outside the range of current ratings common to series  $X$  and  $Z$  already tested.
- c) The rated breaking currents at rated voltages  $U_X$  and  $U_Z$  are the same, or, if they are different, only the lower value is assumed to be applicable to  $U_Y$ .
- d) The rated minimum breaking currents of fuse-links of the same current ratings at rated voltages  $U_X$  and  $U_Z$  are the same, or, if they are different, only the higher value is assumed to be applicable to  $U_Y$ .
- e) The rated frequencies are the same.
- f) All materials are the same.
- g) All dimensions except the length of the fuse-links and of the fuse-elements are the same.
- h) For each current rating, the number of individual fuse-elements and their cross section are the same; also the law governing the variation of the cross section expressed as the number of variations per unit length must be kept constant when interpolating the length of the fuse-elements of intermediate voltage ratings.
- j) The length of the fuse-elements is linearly interpolated with respect to the voltage ratings already tested.

**6.5.5 Extension of the Principle of Homogeneous Series to Fuse-Links of Different Lengths**

**6.5.5.1 General** — When different barrel lengths dependent on the current ratings are used in a range of fuse-links, the fuse-links as a whole do not form a homogeneous series according to the criteria defined in 6.5.3.1.

In fact, though the whole range comprises several homogeneous series each of them complying with the requirements of 6.5.3.1, the fuse-links as a whole do not meet the criteria (c) and (f) of 6.5.4 because:

- a) the fuse-elements have the same length but the barrels do not,
- b) the minimum current rating in one barrel length may be lower than the maximum current rating in a shorter barrel.

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However, performance and behaviour of such fuse-links are sufficiently close to make testing of all current ratings unnecessary.

The following sub-clauses define the requirements to be met by the fuse-links and the tests to be made.

**6.5.5.2 Special requirements** — In addition to the requirements specified in 6.5.3.1 and modified in 6.5.5.1, the fuse-links shall comply with the following:

- a) The fuse series does not contain any deliberately added gas-evolving material other than an explosive charge used to operate a striker or indicator;
- b) No pressure relief exists, excluding any resulting from the operation of a striker or indicator; and
- c) The nominal diameter of the barrel remains constant within usual manufacturing tolerances and the length of the barrel does not exceed 1.6 times the length of the shortest.

**6.5.5.3 Tests to be made** — The first homogeneous series corresponding to both the lowest current ratings and the shortest length of barrel is represented by the suffix 1 and any other homogeneous series by the suffix x.

$L_1, L_x$  = length of the barrel

$A_1, A_x$  = fuse-link of lowest current rating

$C_1, C_x$  = fuse-link of highest current rating

The tests shall be made as follows:

- a) The first individual homogeneous series 1 is to be tested in accordance with 6.5.3.2.
- b) For any other individual homogeneous series x:
  - 1) the fuse-link  $C_x$  of highest current rating is to be tested to test duties 1, 2 and 3;
  - 2) test duties 1 and 2 of fuse-link  $A_x$  are not required provided that in the smallest barrel size 1, the fuse tested has the same number of elements, or less, of the same or smaller cross section than fuse  $A_x$ .

Breaking tests of fuse-link  $A_x$  to test duty 3 are not required provided that:

$$n_{A_x} \geq n_{A_1} \text{ and } S_{A_x} \leq S_{C_1}$$

where  $n_{A_x}$  is the number of fuse-elements in  $A_x$  and  $S_{A_x}$  is the cross section of the individual fuse-elements  $A_x$ .

The minimum breaking current of fuse-link  $A_x$  is deemed to be the same as that of fuse-link  $C_x$ ; if the manufacturer claims a lower value, this must be proved by a separate test.

**NOTE** — This corresponds to the third case ( constant  $S$ , increase of  $n$  ) referred to in Table 9 because if  $A_x$  is in accordance with the second case ( constant  $n$ , increase of  $S$  ), it is already exempted from test duty 3.

## 6.6 Tests for Time/Current Characteristics

### 6.6.1 Test Practices

**6.6.1.1 Ambient air temperature** — The time/current characteristics shall be verified at any ambient air temperature between 22°C and 32°C.

At the beginning of each test, the fuse shall be approximately at ambient air temperature.

**6.6.1.2 Arrangement of the equipment** — The tests shall be made with the same arrangement of the equipment as for the temperature-rise tests if they are made separately ( *see* 6.4.1.2 ) or for the breaking tests ( *see* 6.5.1.4 ).

In particular:

- a) the fuse-base shall be as specified by the manufacturer for the fuse-link being tested.
- b) the size and the length of conductors connected to the terminals shall be as specified in 6.4.1.2.
- c) oil-tight fuse-links shall be tested in an oil-filled enclosure designed to simulate service conditions.

**6.6.2 Test Procedures** — Time/current tests shall be conducted as follows.

**6.6.2.1 Pre-arcing time/current tests** — Pre-arcing time/current tests may be made at any convenient voltage with the test circuit so arranged that the current through the fuse is held to an essentially constant value.

Time/current data obtained from breaking tests may be used.

**6.6.2.2 Time range** — Tests shall be made in the following time ranges:

- a) Back-up fuses: from 0.01 second to 600 seconds
- b) General purpose fuses: from 0.01 second to 1 hour

**6.6.2.3 Measurement of current** — The current through the fuse during time/current tests shall be measured by ammeter, oscillograph or other suitable instrument.

**6.6.2.4 Determination of time** — When times are recorded by oscillograph, the pre-arcing times shall be the virtual or actual times, with indication of the selected method.

**6.7 Oil-Tightness Tests** — Fuse-links of current-limiting fuses designed to be used immersed in oil shall be tested as follows.

NOTE — If several current ratings differing only in their fuse-elements are involved, testing the fuse-link of highest power dissipation is sufficient.

The fuse-link shall be immersed in insulating oil under a pressure of  $7 \times 10^4 \text{ N/m}^2$ . The rated current of the fuse-link shall be passed through it for 2 hour and the temperature of the oil shall be raised ( using supplementary heating if necessary ) to between 75°C and 85°C and maintained within this range for the 2-hour test period.

The current shall be switched off, the supplementary heating discontinued and the oil cooled, or allowed to cool, to a temperature of 22 to 32°C over any convenient period of time.

This cycle shall be carried out six times and the fuse-link shall then be removed from the oil, cleaned externally and opened for inspection of the arc quenching medium, which shall show no sign of ingress of oil.

**6.8 Test of Strikers** — The characteristics of strikers may be verified by the force/travel characteristic of the driving spring or by means of a pendulum.

Machines for testing strikers of medium and heavy type shall be of the 4 N.m type; machines for testing strikers of light type shall be of the 0.5 N.m type.

NOTE — The use of a pendulum as described in ISO Recommendation ISO/R 442-1965\* is recommended but with a smaller impact energy values and impact velocities as specified in ISO/R 179-1961†. For further details reference shall be made to these recommendations.

The hammer of the testing machine shall be provided with a plane steel surface of minimum Vickers hardness 235 HV and of sufficient size normal to the direction of the striker travel, the striker after its specified free travel hitting the quiescently hanging hammer at this plane surface. The striker travel shall be directed to the centre of percussion of the machine and shall be normal to a plane defined by this centre of percussion and by the axis of oscillation of the pendulum.

An alternative method of test of strikers as given in Appendix E is also applicable.

## 7. SPECIAL TESTS

**7.0 Conditions for Making the Tests** — Special tests are made to check whether a type or particular design of fuse corresponds to the characteristics specified and behaves satisfactorily under special specified conditions. They are made on samples to check the specified characteristics of all fuses of the same type.

\*Verification of pendulum impact testing machines for testing steels.

†Plastics — Determination of the Charpy impact resistance of rigid plastics ( Charpy impact flexural test ).

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

For convenience of testing, and with the previous consent of the manufacturer, the values prescribed for the tests, particularly the tolerances, can be so changed as to make the test conditions more severe.

Unless otherwise specified, the tests shall be made according to the test practices specified in 6.2 and as follows.

**7.1 List of Special Tests** — The following tests are to be made after agreement between the manufacturer and the user for certain types of fuses or for special applications:

- a) Thermal shock tests ( for fuses intended to be used outdoors );
- b) Power dissipation tests ( for fuses intended to be used under conditions of restricted cooling differing from those of temperature-rise tests ); and
- c) Radio influence tests ( *under consideration* ).

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

#### **7.1.1 Thermal Shock Tests**

**7.1.1.1 Test sample** — The fuse-base shall be as specified by the manufacturer of the fuse-link being tested.

NOTE — If several current ratings differing only in their fuse-elements are involved, testing the fuse-link of highest power dissipation is sufficient.

**7.1.1.2 Arrangement of the equipment** — The fuse shall be mounted within the directions specified by the manufacturer and connected to the test circuit by bare copper conductors having sizes as specified in 6.4.1.2.

**7.1.1.3 Test method** — The fuse is subjected to 1 hour to a value of current chosen by agreement between manufacturer and user and not exceeding the rated current. Then, the fuse is sprayed with artificial rain at an angle approximately 45° to the vertical, at not higher than room temperature with a rate of precipitation of approximately 3 mm per minute. This spraying shall be maintained for 1 minute with the test current still flowing.

The fuse shall not exhibit any visible external sign of damage.

NOTE — Owing to the wide variety of designs, it is not possible to state a general rule to verify the effect of ingress of water. If a test of waterproofness is requested by the user, such a test shall be defined and made by agreement between the manufacturer and the user.

**7.1.2 Power-Dissipation Tests** — Fuses used under conditions of restricted cooling may require derating. To facilitate this derating, special tests to determine the power dissipation may be made.

These tests are to be made under the conditions specified in 6.4.

The power dissipation is determined when it has reached a steady value for the current value considered. The test shall be made at 50 percent and 100 percent of the rated current. The power dissipation is expressed in watts.

## APPENDIX A

### ( Clause 0.6 )

#### COMPARISON WITH THE CORRESPONDING IEC PUBLICATION

**A-0.** This standard ( Part I ) makes the following major deviations from the IEC Publication referred to in 0.5. [ The clause numbers given refer to those in this standard ( Part I ). ]

*Clause 3.1.1* — For the purposes of this standard, only those rated voltages applicable to Indian system conditions are recognized. These values are those chosen from those indicated as Series I in IEC Publication. This standard also includes 145 kV current limiting fuses.

*Clause 3.2.1* — This standard also covers fuse-bases of rated current of 630 A, to cater to indigenous manufacturing range.

*Clause 3.4* — Fuses covered by this specification are intended for rated frequency of 50 Hz. For guidance on fuses rated for 60 Hz, reference should be made to the IEC Publication referred to in 0.5.

*Table 3 Switching Voltages* — The switching voltage values are under review with particular reference to Indian conditions. Till such time, the data are evolved, values for switching voltages recommended by IEC ( Table 3 ) are recommended.

*Clause 3.12, Table 5 Characteristics of Strikers* — The current practices in the country takes into account three types of strikers, light, medium and heavy as shown in Table 5.

These corresponds to the types recommended by IEC. It is recognized at the international level, that in future two types of strikers could satisfy all requirements.

*Clause 5.2 ( g )* — Item ( g ) 'direction of striker ( if fitted )' has been added to meet the requirement of the user.

*Clause 6.4.1.2, Table 6* — Appropriate size of bare copper conductors suitable for the purposes of temperature-rise test on fuses of 630 A are included. In addition, use of aluminium conductors is recommended with guidance on the appropriate sizes for the same.



*Clauses 6.6.1.1 and 6.7* — The permissible tolerance on reference temperature ( 27°C ) for conducting time/current characteristics test and oil-tightness test has been indicated as  $\pm 5^{\circ}\text{C}$  ( that is a range 22 to 32°C ) to suit Indian conditions.

*Clause 6.8* — An alternate method of test of strikers is included in order to cater to the need of recommending electrical parameters for test circuits to enable unnecessary high power tests to be avoided.

*Clause B-1.1* — The reference temperatures correspond to the conditions prevalent in the country.

## APPENDIX B

### ( Clause 1.4 )

#### NORMAL SERVICE CONDITIONS

##### B-1. SERVICE CONDITIONS

**B-1.0 General** — This standard applies to current-limiting fuses under the following conditions. If the fuses are to be used under conditions different from those mentioned in B-1.1 to B-1.5, the manufacturer should be consulted.

**B-1.1** The reference temperatures assumed for purpose of the specification are:

- |   |      |
|---|------|
| a) Maximum ambient air temperature  | 45°C |
| b) Maximum daily average ambient air temperature                                | 35°C |
| c) Maximum yearly average ambient air temperature                               | 30°C |
| d) Maximum temperature due to sunlight ( equivalent to black body temperature ) | 80°C |

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

##### B-1.2 Altitude not Exceeding 1 000 Metres

NOTE 1 — The rated voltages and insulation levels specified in this standard apply to high voltage fuses intended for use at altitudes not exceeding 1 000 m and for temperature conditions specified above. In selecting a fuse for use at altitudes exceeding 1 000 m, one or other of the following procedures should be adopted:

- The test voltages for insulating parts in air should be determined by multiplying the value of the standard test voltages by the appropriate correction factor in col 2 of Table 9.
- In some cases, it may be more economical to select a higher rated voltage such that when it is multiplied by the appropriate correction factor as given in col 3 of Table 9, the resulting voltage is not lower than the highest service voltage of the system.

NOTE 2 — The rated current or the temperature-rise specified in the standard can be corrected for altitudes exceeding 1 000 m by using appropriate factors given in Table 10, col 2 and 3 respectively. Use shall be made of one correction factor from col 2 or col 3 but not both, for any one application.

**TABLE 9 CORRECTION FACTOR FOR RATED VOLTAGE AND TEST VOLTAGE FOR ALTITUDES**

( Clause B-1.2 )

MAXIMUM ALTITUDE	CORRECTION FACTOR FOR TEST VOLTAGE REFERRED TO SEA LEVEL	CORRECTION FACTOR FOR RATED VOLTAGE
(1)	(2)	(3)
m		
1 000	1.0	1.0
1 500	1.05	0.95
3 000	1.25	0.80

**TABLE 10 CORRECTION FACTOR FOR RATED CURRENT AND TEMPERATURE-RISE FOR ALTITUDE**

( Clause B-1.2 )

MAXIMUM ALTITUDE	CORRECTION FACTOR FOR RATED CURRENT	CORRECTION FACTOR FOR TEMPERATURE-RISE
(1)	(2)	(3)
m		
1 000	1.0	1.0
1 500	0.99	0.98
3 000	0.96	0.92

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 given above, both for the purposes of Tables 9 and 10.

**B-1.3** The ambient air is not excessively ( or abnormally ) polluted by dust, smoke, corrosive or inflammable gases and vapour or salt.

**B-1.4** For indoor installations, only the normal condensation is present.

**B-1.5** For outdoor installations, the wind pressure does not exceed  $700 \text{ N/m}^2$ ,

**APPENDIX C****( Clause 3.11.1 )****METHOD OF DRAWING THE ENVELOPE OF THE PROSPECTIVE TRANSIENT RECOVERY VOLTAGE OF A CIRCUIT AND DETERMINING THE REPRESENTATIVE PARAMETERS****C-1. INTRODUCTION**

**C-1.1** The transient recovery voltage wave may assume several different forms, both oscillatory and non-oscillatory.

When the wave approaches that of a damped oscillation at one single frequency, the envelope is made up of two consecutive linear segments. The envelope shall reflect as closely as possible the actual shape of the transient recovery voltage. The method described here enables this aim to be achieved in the majority of practical cases with sufficient approximation.

**NOTE** — Nevertheless, some cases may arise where the proposed construction would lead to parameters quite obviously more severe than would be justified by the transient recovery voltage curve. Such cases should be dealt with as exceptions and should therefore form the subject of an agreement between the manufacturer and the user or the test laboratory.

**C-2. DRAWING THE ENVELOPE**

**C-2.1** The following method is used for constructing the line segments forming the envelope of the prospective transient recovery voltage curve:

- a) The first line segment passes through the origin  $O$ , is tangential to the curve, and does not intersect the curve.

In the case of curves whose initial portion is concave towards the left, the point of contact is often in the vicinity of the first peak ( *see* Fig. 12, segment  $OA$  ).

If the concavity is towards the right, as in the case of an exponential, the point of contact is at the origin ( *see* Fig. 13, segment  $OA$  ).

- b) The second line segment is a horizontal line tangential to the curve at its highest peak ( *see* Fig. 12 and 13, segment  $AC$  ).

The two-parameter envelope  $O, A, C$ , is then obtained.

**C-3. DETERMINATION OF PARAMETERS**

**C-3.1** The representative parameters are, by definition, the co-ordinates of the point of intersection of the line segments constituting the envelope.

The two parameters  $u_c$  and  $t_s$ , shown in Fig. 12 and 13, can be obtained as co-ordinates of the point of intersection  $A$ .

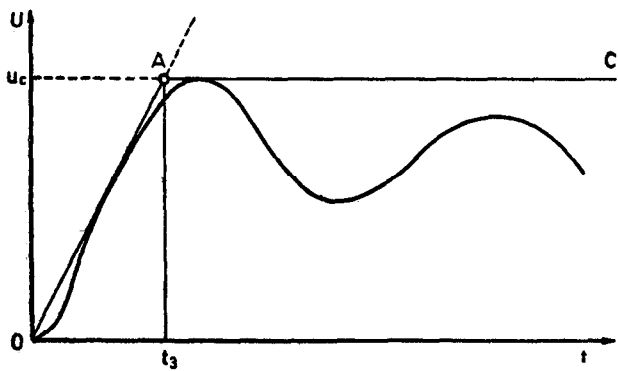


FIG. 12 REPRESENTATION BY TWO PARAMETERS OF AN INHERENT TRANSIENT RECOVERY VOLTAGE OF A CIRCUIT

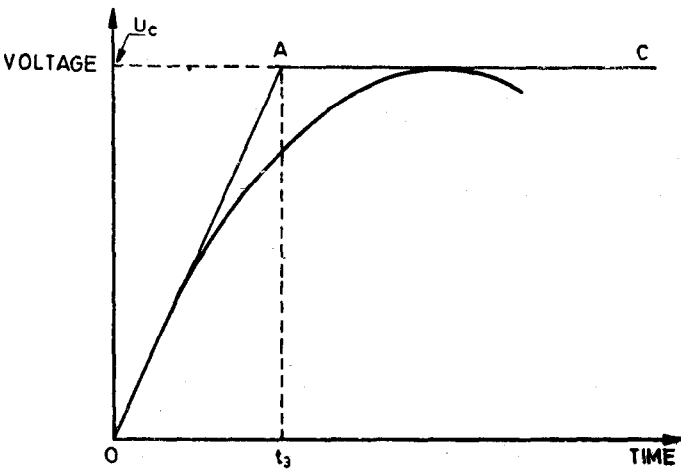


FIG. 13 EXAMPLE OF A TWO-PARAMETER REFERENCE LINE FOR A TRV WHOSE INITIAL PORTION IS CONCAVE TOWARDS THE LEFT

## APPENDIX D

## ( Clause 6.5.1.2 )

REASONS WHICH LED TO THE CHOICE OF TRV VALUES  
FOR TEST DUTIES 1, 2 AND 3

**D-1.** A high-voltage fuse shall operate satisfactorily under all normal service conditions and break the circuit without causing too high a switching voltage. The breaking tests specified in this standard should therefore represent, as far as possible, the most onerous conditions normally met in service. Because fuses are used in the same networks as circuit-breakers, it might seem logical to use the same prospective TRV values as have been specified in standards for high voltage circuit-breakers. However, careful study has shown that these values would not be suitable for tests on fuses due to the different principles involved in circuit interruption by circuit-breakers or by fuses.

**D-2.** Like a circuit-breaker, a fuse may cause transients in the recovery voltage after current zero, but it also produces a high arc voltage which may be dependent on the characteristics of the circuit as determined by the TRV conditions. It is therefore necessary to consider two fundamentally different effects of these test circuit parameters; the effect on the arc voltage and the effect on the transient recovery voltage.

Fuse failures could be caused either by an excessive peak voltage during arcing or by voltage after arc extinction which is itself excessive or produces repetitive restriking. The tests should therefore prove that neither of these types of failure occurs.

**D-3.** It has been found necessary to test fuses at three different prospective breaking currents  $I_1$ ,  $I_2$  and  $I_3$  corresponding to test duties 1, 2 and 3 in Table 7. Since tests at  $I_3$  usually cover the performance at small overload currents, it is only necessary to cover the full range of prospective short-circuit currents in tests at  $I_1$  and  $I_2$  which sometimes differ very widely from each other. In general,  $I_2$  varies between 0.2 percent and 100 percent of  $I_1$ , depending on the current rating, the rated breaking current and the design of a particular fuse. The wide range of prospective breaking currents, each associated with an infinite variety of TRV conditions, can only be covered by the two test currents by taking account of the empirical knowledge of the behaviour of current-limiting fuses. Based on present knowledge of fuse techniques and on experimental evidence, the following facts were taken into consideration.

**D-4.** During its arcing time, a fuse is absorbing such an amount of energy that transient voltage oscillations, due to the inductance and capacitance of the circuit, are generally completely damped out. The only exception may

occur during the first few microseconds after melting, while the arc is being established. During this period, the arc is still in relatively cool surroundings and the damping effect by energy absorption can be small, resulting in high peak transient voltages if the arc voltage rises very steeply to a higher voltage than the crest of the source voltage.

However, in the majority of the fuse designs marketed today, the arc voltage does not rise in this way and excessive arc voltages are not usually produced.

**D-5.** Further, transients will only be generated in the recovery voltage if, immediately before or after current zero, there is a step change from arc voltage to the circuit emf or by chopping of the current. Because of the residual conductivity of the hot arcing products in a blown fuse-link, severe chopping does not take place and the voltage step is the only condition which has to be considered.

**D-6.** Because the fuse absorbs a large amount of energy during the arcing period, the power factor can be considered as shifting from its original value towards unity. The actual current zero is thus nearer the voltage zero than it would be in the same circuit without any arc voltage. With the very high currents, defined by  $I_1$ , there is practically no voltage step at current zero and consequently recovery voltage transients are not produced.

However, with test duty 2, the shift of power factor is less pronounced and the value of the circuit emf at current zero is sufficient to produce a voltage step and considerable transients. This difference in behaviour of fuses at currents of  $I_1$  or  $I_2$  is due to the different amounts of energy stored in the magnetic fields of the circuit inductance at the maximum cut-off current. The value of  $I_2$  is deliberately chosen to produce conditions giving the maximum value of stored energy, and hence minimum power-factor shift, so that the maximum voltage step is likely with this test current rather than with  $I_1$ . In the first few milliseconds after current zero, the hot products of the arc are still in a conducting state and this conductivity decreases, due to heat dissipation, slowly in comparison with the time constants of the transient voltage. In fuse testing, this conductivity produces additional damping of transients in the recovery voltage. However, the amount of damping is proportional to the characteristic impedance  $\sqrt{L/C} = 2\pi f_o L$  of the circuit. As a result, transients of higher natural frequency  $f_o$  are more effectively damped than those of lower frequency. These lower frequency transients are therefore sustained longer and, since these are imposed on the power-frequency recovery voltage, may produce an extra voltage stress on the blown fuse-link particularly if they persist until the crest value of the power-frequency recovery voltage is reached. Failures have occurred due to restrikes caused by this extra stress and the test specifications must therefore take account of this condition.

**D-7.** The above considerations may be summarized as follows:

The arc voltage of a fuse is not significantly affected by the TRV conditions of the circuit, except during the first few milliseconds after melting.

Whether transients in the actual recovery voltage will be produced depends on the value of the breaking current. The highest transients are to be expected with test currents  $I_2$  of test duty 2, and the transients with the lower natural frequencies are the more harmful. If test current  $I_1$  is very high compared with  $I_2$ , it does not usually produce transients.

**D-8.** Since it was desirable that the TRV characteristics for fuses and circuit-breakers should be the same, it was decided to accept the standardized values specified in the relevant standard on high voltage circuit-breakers. However, bearing the above factors in mind, the following decisions were taken as regards the tests:

- a) *Test Duty 1* — Since transients are not generated in the actual recovery voltage, the prospective TRV conditions are irrelevant and therefore not specified. The exceptional case, where the TRV conditions can influence the peak arc voltage, has been covered separately.
- b) *Test Duty 2* — Since low-frequency transients have been shown to be more harmful, appropriate values to produce a typical low-frequency prospective TRV have been derived from the circuit parameters specified for circuit-breakers. Assuming single-frequency oscillations, these values represent  $\frac{1}{4}$  to  $\frac{1}{3}$  of the lowest frequencies for the relevant voltages. In addition, the figures of peak voltage have been based on an amplitude factor of 1.5, as compared with 1.4 in Table 4.
- c) *Test Duty 3* — This publication does not specify TRV conditions; instead 6.5.1.2 specifies that a resistor is to be shunted across the circuit reactances in order to obtain complete suppression of oscillating transients. However, experience has shown that this suppression is sometimes not obtained, particularly in circuits of very low natural frequency, when the resistor is of the value specified. These values have therefore been modified to ensure that at least critical damping is achieved regardless of the natural frequency of the test circuit.

## APPENDIX E

### ( Clause 6.8 )

#### ALTERNATIVE TESTS FOR STRIKERS

**E-0.** The energy and travel requirements specified in 3.12 shall also be verified by the following test procedure. Only fuse-links having end-to-end striker circuits are covered.

#### E-1. TEST SAMPLES

**E-1.1** Tests shall be made on dummy fuse-links which are identical in all respects with the actual fuse-link except that:

- a) There are no main elements
- b) The series wire shall be reduced in length so that the resistance of the igniter wire plus the resistance of the series wire shall be approximately equal to

$$R_n = \frac{415}{U_n}$$

where,  $R_n$  is the declared normal resistance of the striker circuit of the fuse-link type,

$U_n$  is the rated voltage of the actual fuse-link ( The highest voltage rating where there is more than one rating specified for the fuse-link ).

#### E-2. PREFERRED CHARACTERISTICS OF PENDULUM ( see 6.8 ).

#### E-3. TEST CONDITIONS

**E-3.1** Tests shall be made on three dummy fuse-links. The test parameters shall be as follows:

Applied voltage	: 415 V ac $\pm$ 10 percent
Prospective current	: Not less than 100 A
Power factor	: Any convenient value
Striker	: After its specified free travel ( Table 5 ) the striker shall hit the quiescently hanging hammer at its plane surface. The striker travel shall be directed to the centre of the percussion of the machine and shall be normal to a plane defined by this centre of percussion and by the axis of oscillation of the pendulum

#### E-4. TEST REQUIREMENTS

**E-4.1** Three tests shall be made. For each test the striker pin-travel and energy output shall be within the limits specified in 3.12.



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