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Specification for

Fuses for voltages exceeding 1000 V a.c. —

Part 2: Expulsion fuses

UDC 621.316.923

Co-operating organizations

The Electrical Industry Standards Committee under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

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Air Ministry*
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British Electrical and Allied Industries Research Association*
British Electrical and Allied Manufacturers' Association*
British Electrical Development Association
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Central Electricity Authority and Area Boards*
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National Coal Board
South of Scotland Electricity Board

This British Standard, having been approved by the Electrical Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 30 January 1956

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Contents

Foreword

This standard makes reference to the following British Standards:

BS 116, *Oil circuit-breakers for alternating current systems.*

BS 148, *Insulating oil (low viscosity type) for transformers and switchgear.*

BS 923, *Impulse-voltage testing.*

BS 2782, *Methods of testing plastics.*

This British Standard has been prepared to meet the need for a standard for fuses for a.c. circuits above 1 000 volts, which is the upper limit of voltage for fuses covered by BS 88. It is expected that additions to the standard will become necessary as knowledge increases and, in particular, it is hoped to standardize dimensions to some extent when adequate experience has been gained with fuses in accordance with this standard. Some time must necessarily elapse before every such fuse can be supplied and certified to comply with the standard in all respects; in the meantime therefore its application should be subject to agreement between the contracting parties.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 48, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Section 1. General

1 Scope

This British Standard relates to fuses for use indoors or outdoors on alternating current systems having line-to-line voltages above 1 000 volts at a frequency of 50 cycles per second, and with breaking-capacities corresponding to three-phase values from 25 MVA to 750 MVA for power fuses and from 50 MVA to 2 500 MVA for voltage-transformer fuses (or equivalent values for other systems).

In general, these fuses are suitable for short-circuit protection only, leaving other devices for protection against over-currents.

The requirements of this standard apply to fuses for use in air and to fuses for use immersed in oil.

This standard relates only to expulsion fuses.

Where fuses depend for their correct operation as fuses on the movement of some component to provide an insulating gap, this feature is considered as part of the fuse operation and comes within the scope of this standard.

On the other hand, there are fuse-links that contain tripping devices for initiating the opening of a switch. These fuse-links are required to comply with this standard, but the satisfactory operation of the equipment operated by the tripping devices is outside the scope of the standard.

The range of breaking-capacity ratings of 25 MVA to 750 MVA covers the usual applications of high-voltage fuses for power-system and voltage-transformer protection. It is recognized, however, that voltage-transformer fuses may also be required for use on systems having short-circuit capacities in excess of 750 MVA. Where such fuses are designed to operate in series with current-limiting impedances, the values of which are more than 100 times the impedance of the system, their performance is practically unaffected by the short-circuit current of the system, hence they may be safely used, with the appropriate impedance, on circuits having greater short-circuit capacities than 750 MVA. Voltage-transformer fuses without current-limiting impedances for use on systems with short-circuit currents greater than those corresponding to 750 MVA may be deemed to comply with this standard provided that all the requirements other than the tests set out in Clauses **27** and **28** are met; in such cases tests for breaking-capacity should be the subject of agreement between purchaser and manufacturer.

2 Basis of specification

a) *General*. This standard is based on single-phase and polyphase service conditions. Fuses complying with it are suitable for operating under a variety of conditions where the recovery-voltage across any fuse may be any voltage not exceeding its voltage-rating. Conditions i) and ii) below are examples in which a three-phase group of fuses can break two phases of the circuit and leave the third intact, and so may impose a recovery-voltage equal to the voltage-rating of the fuse across each of the two fuses that have operated.

i) The operation of fuses on a three-phase fault where the neutral of the source of supply is not connected to the fault.

ii) The operation of fuses on a single-phase line-to-line fault on a three-phase system, if the load is not connected to the supply neutral, since under these conditions the fuse in the healthy line is connected to the fault *via* the load.

In view of the above conditions, breaking-capacity tests made on a three-phase basis should have a recovery-voltage across each phase not less than the line-to-line voltage [see Sub-clause **27** l) and Figure 1(a)]. The use of a three-phase 3-wire test circuit with one fuse of a three-phase group of fuses replaced by a link of negligible impedance enables this condition to be achieved. The same circuit may be used to test fuses intended for single-phase duty, two at a time. The test circuit severity on one of the fuses shall comply with the circuit conditions prescribed in Sub-clause **27** g) and for current-limiting fuses also with Figure 2.

Single-phase tests of one fuse of a three-phase group of fuses, or of fuses for single-phase systems shall also comply with the requirements of Sub-clause **27** g). Fuses complying with this standard are suitable for service on single-phase or two-phase systems where the line-to-line voltage is the same as that of a three-phase system for which they have been tested (see Clause **10**).

b) *Breaking-capacity rating*. For the purpose of this standard the breaking-capacity rating of a fuse is expressed as a prospective current at its voltage-rating. When recording the results obtained during breaking-capacity type-tests the prospective current and the recovery-voltage shall be stated. When a fuse exhibits current-limiting characteristics the current broken will be less than the peak current associated with the prospective current. In this case, when assessing the performance of the fuse, it will be deemed to have broken the prospective current.

c) *MVA rating*. For the practical convenience of specifying MVA breaking-capacity ratings for fuses and for comparing a given rating with the MVA value for a short-circuit at a given point in a supply network, the breaking-capacity rating in kilo-amperes assigned to a fuse is converted into an MVA rating by multiplying the former by its voltage-rating in kilovolts and by the phase-factor.

Thus the value of single-phase MVA is the product of single-phase r.m.s. kilo-amperes and the voltage-rating in kilovolts, and the value of three-phase MVA is obtained by multiplying the single-phase r.m.s. kilo-amperes by the voltage-rating in kilovolts and by $\sqrt{3}$ (not by 3).

d) *Severity of duty*. The specification standardizes criteria of severity of duty under which type-tests are made and ratings are assigned. It is recognized that the severity of duty imposed on a fuse may also depend on the form of restriking-voltage, but, since present knowledge is insufficient to enable restriking-voltage characteristics to be standardized, only those factors which control the amplitude of the restriking-voltage have been included. It is generally agreed that the restriking-voltage characteristics obtainable in testing stations are more onerous than those obtained under normal service conditions. The permissible peak value of the transient voltage which may be produced by the fuse is specified [see Sub-clause **28** a) ix)].

3 Definitions

For the purposes of this British Standard the following definitions shall apply:—

3.1
fuse

a device for protecting a circuit against damage from an excessive current flowing in it, by opening the circuit on the melting of a fuse-element by such excessive current. The fuse consists of all the parts that form the complete device, including any current-limiting impedance association therewith

3.2
fuse-element

the part of a fuse which is designed to melt and thus open a circuit

in some designs the fuse-element includes other attachments which are renewed when the fuse is re-wired

3.3
cartridge

a "totally-enclosing" fuse-element container, consisting of insulating material; generally tubular, with its ends enclosed by caps of metal or other material. The term "totally-enclosing" is deemed not to exclude the use of devices in connection with indicating or pressure-release

3.4
cartridge-fuse

a fuse in which the fuse-element is enclosed in a cartridge

3.5
oil-tight cartridge-fuse

a cartridge-fuse which excludes oil from the interior of the cartridge when totally immersed in oil, and in which the oil plays no part in arc extinction

3.6
powder-filled cartridge-fuse

a cartridge-fuse in which the fuse-element is enclosed in a cartridge containing an arc-quenching powder

3.7
liquid-fuse

a fuse in which the fuse-element is enclosed in an insulating container filled to an appropriate level with an arc-quenching liquid

3.8
oil-tank fuse

a fuse in which the fuse-link is totally immersed in an oil tank, the oil acting as the arc-extinguishing medium

3.9
expulsion-fuse

a fuse in which the length of break is increased by expulsion of part or all of the fuse-element and/or in which arc-quenching is assisted by the movement of vapour from the container. The vapour may be generated wholly by the volatilization of the fuse-element or partly by the effect of heat on a solid substance carried either by the fuse-link or by the inner wall of the container

3.10
current-limiting fuse

a fuse which by its mode of operation at the initiation of arcing limits the current by cut-off (see Definition **3.23**, Appendix A and Figure 5)

3.11
tripping-fuse

a fuse that contains an auxiliary device for the purpose of tripping other apparatus such as a switch

3.12
voltage-transformer fuse

a fuse for use in the primary circuit of a voltage-transformer

NOTE A current-limiting impedance (usually resistance) may be used in series with a voltage-transformer fuse. In certain types of voltage-transformer fuse the current-limiting impedance is inherent in the high resistance of the fuse-element. Alternatively, or in addition, the fuse may be of the current-limiting type.

3.13
fuse-link

that part of a fuse which comprises a fuse-element and a cartridge or other container, if any, and is either capable of being attached to fuse-contacts or is fitted with fuse-contacts as an integral part

3.14
fuse-contact

a contact suitable for engaging with a fixed contact, and capable of having a fuse-link attached to it or of forming an integral part of a fuse-link

3.15
fuse-carrier

a removable holder serving to carry a fuse-link and fitted with fuse-contacts, if necessary, for this purpose. A cartridge or other container of a fuse-element, if suitable, may form a fuse-carrier or part of a fuse-carrier

3.16
fixed contact

a contact suitable for engaging with a fuse-contact, and connected to a terminal to which the circuit conductor is connected

3.17
fuse-mount

an assembly comprising a base, insulators and fixed contacts

3.18
fusing-current

the r.m.s. current which will melt the fuse-element in any specified time from the commencement of current flow

3.19
minimum fusing-current

the minimum r.m.s. current at which a fuse-element in a fuse will melt

3.20
current-rating

the r.m.s. current stated by the manufacturer to be the current that the fuse will carry continuously without deterioration, in accordance with the relevant clauses of this standard

3.21
voltage-rating

the voltage stated by the manufacturer to be the highest declared r.m.s. voltage allowable between the conductors of a circuit in which the fuse or the group of fuses may be used

3.22
prospective current

the r.m.s. value of the alternating component of the current that flows in the circuit due to the applied voltage when the fuse including its series current-limiting impedance (if any) is replaced by a link of negligible impedance, but without any other circuit change

3.23
cut-off

if the melting of a fuse-element prevents the current through the fuse from reaching the otherwise attainable maximum (the peak of the first major loop), the fuse is said to "cut off", and the instantaneous maximum current attained is called the cut-off current

NOTE 1 In an a.c. circuit the numerical value of the cut-off current may be greater than the numerical value of the prospective current. (See Definition **3.22** and Appendix D.)

NOTE 2 A fuse only exhibits cut-off at prospective currents greater than a particular value; this value varies with different fuses and may be at a prospective current greater than the breaking-capacity rating.

3.24
breaking-capacity rating

the prospective current that can be broken by a fuse at its voltage-rating under prescribed conditions. For practical convenience it may be stated in rated MVA

3.25
recovery-voltage

the normal-frequency r.m.s. voltage that appears across the terminals of a fuse after final arc-extinction

3.26
restriking-voltage

the high-frequency transient voltage that exists across the fuse terminals at, or in close proximity to, each zero current pause during the arcing-time; the important characteristics are its amplitude and its rate-of-rise (expressed in volts per micro-second) at the time of final arc-extinction

3.27
arc-voltage

the voltage that exists across the fuse terminals during the arcing-time

NOTE The maximum value of the arc-voltage may exceed the peak value of the recovery-voltage.

3.28
loop

that part of an alternating wave which extends from one zero to the next

NOTE 1 Successive loops may have different durations and amplitudes in the period immediately following the initiation of current.

NOTE 2 For the purpose of indicating the number of current zeros during the arcing-time, arcing-times may be referred to as including a stated number of loops.

3.29
pre-arcing-time

the time between the commencement of a fusing-current and the instant when a break occurs in the fuse-element

3.30
arcing-time

the time between the end of the pre-arcing-time and the instant when the circuit is broken and the current becomes permanently zero

3.31
total operating-time

the sum of the pre-arcing-time and the arcing-time (See Definitions **3.29** and **3.30**.)

3.32
virtual time of a period of operation of a fuse

the time for which a steady current equal to the prospective current would have to flow in a fuse to produce the same quantity of energy as would be produced if the actual current during the period of operation considered flowed in the fuse for the actual period (see Clause **12**)

this time is calculated from the formula:

$$t_v = \frac{\int i^2 \, dt}{I_p^2}$$

in which

i is the instantaneous value of current,

I_p is the prospective current, and

t_v is the virtual time of the period of operation under consideration.

3.33
operation

the process in a fuse between the beginning of the pre-arcing-time and the end of the arcing-time

3.34
type-test

a test of one article intended to show that all articles of the same kind and made to the same specification would pass an identical test

3.35
routine test

a test of every article made to the same specification

3.36
insulation co-ordination

the process of correlating the insulation strengths of electrical equipment with anticipated over-voltages and with the characteristics of protective devices (see Appendix H). It consists of the steps taken to prevent damage to electrical equipment due to over-voltages, and to localize flashovers (as far as economically practicable) to points where they will not cause damage

3.37
insulation level of apparatus

the level that determines the dielectric strength of apparatus, and which is expressed for impulse-tested apparatus by a peak impulse value (impulse withstand voltage with full 1/50 microsec wave) and for non-impulse-tested apparatus by a power-frequency r.m.s. voltage value (power-frequency withstand voltage) which the apparatus should withstand under specified test conditions

3.38
electrically exposed installation

an installation in which the apparatus is subject to over-voltages of atmospheric origin

NOTE 1 Such installations are usually connected to overhead transmission lines, either directly or through a short length of cable.

NOTE 2 Apparatus may be required for installations which are partly exposed to over-voltages of atmospheric origin, that is, exposed to voltages of magnitude less than for an exposed installation. Such installations are usually connected to overhead transmission lines through two-winding transformers, or a longer length of cable, which reduce the amplitude of incoming over-voltages. These cases require special consideration. The apparatus will be chosen from the appropriate exposed or non-exposed insulation class, as a special class of insulation is not proposed for this case.

3.39
electrically non-exposed installation

an installation in which the apparatus is not subject to over-voltages of atmospheric origin

NOTE Such installations are usually connected to cable networks.

3.40
effectively earthed system

one in which during a line-to-earth fault the maximum voltage to earth of the other two lines expressed as a percentage of the line-to-line voltage does not exceed 80 per cent

NOTE 1 A value not exceeding 80 per cent is obtained when for all switching conditions and unlimited supply the ratio of the zero-sequence reactance to the positive-sequence reactance is less than three, and the ratio of the zero-sequence resistance to the positive-sequence reactance is less than unity.

NOTE 2 A system in which all the transformers have star connected windings with all neutrals solidly (directly) earthed (i.e. the multiple earthed system) is regarded as effectively earthed. If only a limited number of transformers are so earthed, the system will not necessarily be effectively earthed.

3.41
non-effectively earthed system

one in which, during a line-to-earth fault, the maximum voltage to earth of the sound lines exceeds 80 per cent of the line-to-line voltage

Section 2. Rating

4 Voltage-rating

The following are the standard voltage-ratings for fuses:

3.3 kV	33 kV
6.6 kV	66 kV
11 kV	

Non-preferred voltage-ratings for fuses are as follows:

2.2 kV	110 kV
22 kV	132 kV
88 kV	

5 Current-rating

Fuses shall have one of the values of current-rating given in Table 1 or Table 2. Some fuses of the higher current-ratings may not be available in all types or in all the breaking-capacity ratings in Table 3 or Table 4.

Table 1 — Current-ratings for fuses other than voltage-transformer fuses

Amperes
5
10
15
20
25
30
40
50
60
75
100
150
200

NOTE It is recognize that fuses with current-ratings other than those specified in Table 1 and Table 2 are in present use, and that some time may elapse before all fuses can be made and supplied to the above ratings.

Table 2 — Current-ratings for fuses primarily used for the protection of voltage-transformers

Amperes
0.5
1
2
3

NOTE 1 It is recognized that fuses with current-ratings other than those specified in Table 1 and Table 2 are in present use, and that some time may elapse before all fuses can be made and supplied to the above ratings.

NOTE 2 It is recognized that the current-ratings of the fuse and of the current-limiting impedance may not be the same. Where a fuse is used in series with a current-limiting impedance, the current-rating of the combination is that of the component with the smaller current-rating.

6 Breaking-capacity ratings

Fuses shall have one of the breaking-capacity ratings specified in Table 3 or Table 4.

Table 3 — Standard 3-phase breaking-capacity ratings for fuses other than voltage-transformer fuses

1	2	3
Standard voltage-rating	**Standard 3-phase breaking-capacity rating**	**Standard 3-phase breaking-current corresponding to MVA in Col. 2**
kV	MVA	kA
2.2[a]	25[a]	6.57[a]
	50[a]	13.1[a]
	75[a]	19.7[a]
	100[a]	26.3[a]
3.3	**25**	**4.38**
	50	**8.76**
	75	**13.1**
	100	**17.5**
	150	**26.3**
6.6	**50**	**4.38**
	75	**6.57**
	100	**8.76**
	150	**13.1**
	250	**21.9**
11	**50**	**2.63**
	75	**3.94**
	100	**5.25**
	150	**7.88**
	250	**13.1**
22[a]	75[a]	1.97[a]
	100[a]	2.63[a]
	150[a]	3.94[a]
	250[a]	6.57[a]
	350[a]	9.2[a]
	500[a]	13.1[a]
33	75[a]	1.31[a]
	100[a]	1.75[a]
	150[a]	2.63[a]
	250	**4.38**
	350	**6.13**
	500	**8.76**
66	250[a]	2.19[a]
	350[a]	3.06[a]
	500	**4.38**
	750	**6.57**

NOTE It is recognized that fuses are made for voltages up to 132 kV, but this standard does not contain any recommendations regarding the breaking-capacity of fuses for voltages above 66 kV.

[a] These are non-preferred ratings.

Table 4 — Standard 3-phase breaking-capacity ratings for voltage-transformer fuses

1	2	3
Standard voltage-rating	**Standard 3-phase breaking-capacity rating**	**Standard 3-phase breaking-current corresponding to MVA in Col. 2**
kV	MVA	kA
2.2[a]	75[a]	19.7[a]
	100[a]	26.3[a]
	150[a]	39.4[a]
3.3	**50**	**8.76**
	75	**13.1**
	150	**26.3**
	250[a]	43.8[a]
6.6	**150**	**13.1**
	250	**21.9**
	500[a]	43.8[a]
11	**150**	**7.88**
	250	**13.1**
	500	**26.3**
	750[a]	39.4[a]
22[a]	250[a]	6.57[a]
	500[a]	13.1[a]
	750[a]	19.7[a]
	1 500[a]	39.4[a]
33	**500**	**8.76**
	750	**13.1**
	1 500	**26.3**
66	750[a]	6.57[a]
	1 500	**13.1**
	2 500	**21.9**

NOTE It is recognized that fuses are made for voltages up to 132 kV, but this standard does not contain any recommendations regarding the breaking-capacity of fuses for voltages above 66 kV.

[a] The are non-preferred ratings.

Section 3. Marking

7 Fuse-links

All fuse-links shall be indelibly marked with:

a) Current-rating (see Clause **5**).

Where unwired fuses are sent out by the manufacturer, the maximum permissible current-rating of the fuse-element shall be clearly stated by the manufacturer, and a blank space shall be left on the fuse for filling in the current-rating of fuse-element used. Fuse-elements for re-wireable fuses shall be marked with their current-rating.

b) Voltage-rating (see Clause **4**).

The fuse-link may be marked with any combination of the voltages for which it is suitable as proved by test.

c) Manufacturer's identification code.

If the construction of the fuse provides sufficient space, it is desirable to include:

d) Breaking-capacity at voltage-rating . . . kA. r.m.s.

e) Value of current-limiting impedance (if any) in ohms — see Note to Definition **3.12**.

f) The number of this British Standard (BS 2692).

8 Current-limiting impedances

All current-limiting impedances separate from the fuse shall be indelibly marked with:

a) The impedance in ohms.

b) An indication of the fuse with which the impedance is to be used.

c) Manufacturer's identification code.

Section 4. Service conditions

9 Service conditions

High-voltage fuses complying with this standard are suitable within the limits of their rating for installation where the conditions are those specified below.

a) *Voltage.* A voltage available across a fuse after operation not greater than the voltage-rating of the fuse.

b) *Current.* The carrying of currents from zero current to rated current and the breaking of fusing-currents up to the breaking-capacity rating (see Appendix A).

c) *Ambient temperature.* Ambient temperature not exceeding 25 °C.

(For other ambient temperatures see Clause **14**.)

d) *Altitude.* An altitude not exceeding 3 300 feet (1 000 metres) above sea-level. When a fuse intended for service at high altitudes is tested near sea-level the limits of temperature-rise given in Clause **14** shall be reduced one per cent for each 1 000 feet above sea-level at which the fuse is intended to work in service. The correction shall not be applied to altitudes below 3 300 feet (1 000 metres).

e) *Atmosphere.* An atmosphere not subject to excessive pollution by smoke, chemical fumes, salt-laden spray, etc. Such pollution occurs in some industrial areas and in some coastal districts.

NOTE For installation of fuses which emit flame see Sub-clauses **17** a) and **28** a) v).

Section 5. Operation in service

10 General requirements

a) A fuse shall be capable of satisfactorily opening the circuit or circuits protected by it under conditions that produce any value of fusing-current not exceeding its breaking-capacity rating at voltages not exceeding its voltage-rating. The behaviour of the fuse shall be satisfactory irrespective of the degree of current asymmetry.

b) When performing operation a) above, a fuse shall not show undue distress as defined below. Any emission shall not cause breakdown or significant electrical leakage to earth or between poles nor shall it cause damage to associated apparatus and it shall neither in quantity nor direction be a source of danger to an operator.

c) Operation of an oil-tank fuse shall not cause emission of flame from the containing tank and provision shall be made to ensure that any gas or oil emitted from the tank is conducted harmlessly away. The construction shall be such that gases cannot collect at any point where ignition can be caused during or after operation of the fuse or by normal operation of the associated apparatus. Carbonization of the oil during the operation shall not be such as to cause breakdown or significant electrical leakage.

d) Operation of a powder-filled cartridge-fuse shall not cause emission of flame or powder.

e) Fuses for use in the tank of a voltage-transformer shall not cause flame, oil or gas emission from the tank during their operation. The construction of the tank shall be such that gases cannot collect at any point where ignition can be caused during or after operation of the fuse or by normal operation of the associated apparatus. Carbonization of the oil during operation shall not be such as to cause breakdown or significant electrical leakage.

f) After the operation described in Sub-clause a) above, a fuse, and current-limiting impedance, if any, shall, without reconditioning, be capable of withstanding its rated voltage without dielectric breakdown, and the fuse-contacts, fuse-carrier and fuse-mount, when fitted with a new fuse-element or fuse-link, shall be capable of carrying rated current at rated voltage without a temperature-rise in excess of that allowable under Clause **14**. All parts of the fuse shall be essentially in the same condition as before the operation, except that the fuse-element will require renewal and parts which assist in extinguishing the arc may require renewal [see Sub-clause **28** b)]. After such renewals the fuse shall comply with this standard in all respects.

11 Liquids

When fuses are immersed in, or filled with, liquid and are installed in localities subject to low temperatures, an appropriate liquid of low freezing-point should be used. When so required the maker shall give the lower limit of temperature for which the fuse may be used.

12 Time/current characteristics[1)]

The manufacturer shall, on request, submit characteristic curves of the fuses showing the relation between pre-arcing-time and prospective current. The performance of fuses with respect to current at any particular value of time shall be within ± 20 per cent.

The measurements for determining the curve shall be made with the fuses initially at a temperature between the limits of 15 °C and 25 °C.

Information shall be given for arcing-time. The manufacturer shall give information on virtual time on request (see Definition **3.32**).

If required, additional curves may be given based on measurements with the fuses initially at the steady temperature which is attained with rated current flowing.

NOTE See Appendix K.

13 Cut-off current characteristic[1)] (For current-limiting fuses only)

The manufacturer shall, on request, submit characteristic curves of the fuses showing the relation between prospective current and maximum cut-off current. The performance of fuses with respect to cut-off current at any particular value of prospective current shall be within ± 20 per cent.

The curve shall be plotted as follows:

abscissae: prospective current

ordinates: maximum cut-off current.

14 Temperature-rise limits at rated current

a) All parts of fuses shall be so designed and proportioned that when they are carrying their rated currents continously in accordance with the requirements of Clause **21** the temperature-rise of the fuse-contacts and of the terminals, or sweating sockets where used, shall not exceed the following values:

	Centigrade degrees
Fuse-contacts	55
Terminals, or sweating sockets where used, to which the circuit conductor is connected	45

b) All parts of current-limiting impedances for use with fuses shall be so designed and proportioned that when they are carrying their rated currents continuously in accordance with the requirements of Clause **21** the temperature-rise of any part shall not exceed 45 Centigrade degrees.

[1)] Standardized methods of presenting the information are under consideration and it is hoped to publish details in due course.

c) The maximum temperature-rises specified are based on an assumed ambient temperature not exceeding 25 °C. For higher service ambient temperatures, the current-ratings of fuses may have to be reduced so that the total temperatures (ambient temperature plus temperature-rise) do not exceed the following values:

	Centigrade degrees
Fuse-contacts	80
Terminals, or sweating-sockets where used, to which the circuit conductor is connected	70

d) When a fuse is intended for service at high altitudes the provisions of Sub-clause **9** d) shall apply.

NOTE For certain types of fuse, which embody a filling medium having a low boiling-point, it may be necessary to design the fuse for a temperature-rise less than that specified above.

Section 6. Construction

15 Components

Components, including filling media, used in the construction of a fuse shall not be such as to cause, during normal service and storage conditions, chemical or electro-chemical deterioration likely to reduce the normal life or prevent satisfactory operation of the fuse.

16 Contacts

Fuse-contacts and fixed contacts shall be so constructed and of such material that when the fuse is properly installed and the service conditions are normal, the requirements of Sub-clauses a), b) and c) are met.

a) Adequate contact between the fuse-contacts and the fixed contacts after repeated engagement and disengagement, and after the fuse has been left untouched for a long period.

b) The fuse-carrier shall be so held in its contacts as to prevent it being unintentionally ejected from the contacts during normal service and short-circuit operation, and

c) Compliance with Clause **14** is maintained.

17 Fuse-links

a) Fuse-links shall be of such construction or so guarded or placed as to prevent danger from over-heating, arcing, and the scattering of hot metal or other substances, when operating in service, or when tested in accordance with this standard.

b) Cartridges with their attached labels, if any, need not be non-ignitable and non-hygroscopic. Tubular linings, if any, enclosing fuse-elements, linings of containing cases or covers, and fillers of cartridges need not be non-hygroscopic but shall be non-ignitable.

c) Fuse-links shall be sufficiently robust mechanically to ensure that no damage results from normal handling and vibration or operation of their associated equipment.

d) Fuse-links for use outdoors shall be of materials which effectively resist deterioration under normal climatic conditions.

e) Oil-tight cartridge fuse-links shall be effectively sealed to prevent the penetration of the oil to the arc-quenching medium during normal service. (See Clause **3**, Definition **3.5**.)

f) Preferred dimensions for a range of three sizes of tag-type fuse-links, for use in air, are given in Figure 12, Figure 13 and Figure 14. Preferred dimensions for a range of ferrule-type fuse-links, for use in air or oil, are given in Figure 15.

The reference letters and numbers used to describe the dimensions in Figure 12 to Figure 15 shall only be assigned to fuse-links complying with these dimensions.

NOTE When the required current rating cannot be obtained in the preferred dimensions for a particular voltage, the dimensions for a higher voltage in the same range should be used if possible.

18 Fuse-carriers and fuse-mounts

a) All non-metallic parts of fuse-carriers (with the exception of the items covered by Sub-clause **17** b), and fuse-mounts shall be constructed of non-ignitable non-hygroscopic insulating materials. Moulded parts shall be of tough, non-ignitable insulating material that, when tested in accordance with the plastic yield test given in BS 2782[2], Part 1, Method 102A, will yield not more than 5 mm at 85 °C. After 24 hours immersion in water the weight of the material shall not have increased by more than one-half of one per cent after all moisture has been removed from its surface. The resistance of the material to water shall not depend on varnish. Ceramic parts shall be of vitrified material such that after 24 hours immersion in water they shall not have increased in weight by more than one-half of one per cent after all moisture has been removed from the surface. The resistance of the material to water shall not depend on glaze. Where fuses are intended for use outdoors, their carriers and mounts shall be of materials which effectively resist deterioration under normal climatic conditions.

b) The fuse-element tube of an expulsion-fuse, of the type which depends for its correct operation on automatic movement of some components to provide an adequate insulating gap, need not be non-hygroscopic but shall be non-ignitable.

19 Current-limiting impedances

Current-limiting impedances shall be sufficiently robust mechanically to ensure that no damage results from normal handling and vibration or operation of their associated equipment, and when used outdoors they shall not deteriorate under normal climatic conditions. The impedance value shall remain substantially constant under all normal service conditions.

Section 7. Type tests

20 General

a) All tests in accordance with this standard shall be type tests except those specified in Section 8, which shall be routine tests. Certificates of type tests shall be considered as evidence of compliance of the fuses with the requirements of the relevant clauses of this standard and the manufacturer shall hold available such certificates, together with detail drawings of the fuses and a record of any alterations made in them subsequent to the type tests. The manufacturer shall, if required by the purchaser, certify that the fuses are identical in material and performance with those covered by certificates of stated date. The fuses used for the type tests shall be mounted in a manner representative of service in all details likely to affect their performance during individual type tests, provided:

i) that in each standard assembly of identical construction and size only the fuse-link giving the maximum current-rating need be tested,

ii) that if a fuse is capable of being made with the same current-rating but with different minimum fusing-currents, the fuse-link giving the highest value of minimum fusing-current shall also be tested if it has not already been tested under i) above.

b) Type tests may be made by the manufacturer or by any other recognized authority.

21 Test for temperature-rise

a) Fuses shall be tested for temperature-rise at their rated currents in an ambient temperature between 15 °C and 25 °C, in surroundings free from external draughts and in one of the containing cases, if any, in which they may be used in service, and if alternative positions are possible in service they shall be mounted vertically for test. The frequency of the supply shall be 50 cycles per second with a tolerance of ± 25 per cent. Fuses intended for use in oil shall be tested in oil.

b) The maximum temperature-rises of the components, as specified in Clause **14**, shall be measured by thermocouples attached by a low-melting-point alloy or by some equally effective means.

c) The points at which the temperature-rises are measured shall be:—

i) For contacts: the point at which, from consideration of the design, the maximum temperature-rise may be expected to occur.

[2] BS 2782, "*Methods of testing plastics*", Part 1: "*Effect of temperature*".

ii) For terminals or, when used, sweating-sockets: the accessible point closest to the external connection.

iii) For current-limiting impedances: the points at which, from consideration of the design, the maximum temperature-rise may be expected to occur.

d) The conductors connected to the fuses during the test shall have a length of not less than 24 in. on each terminal, and shall be in accordance with Table 5.

Table 5 — Temporary test-connections for temperature-rise test

Current-rating of fuse				Size of copper conductor	Covering
		amp.			
	0.5	up to and including	5	3/.029	V.R. or P.V.C.
above	5	up to and including	15	7/.029	V.R. or P.V.C.
above	15	up to and including	30	7/.044	V.R. or P.V.C.
above	30	up to and including	60	19/.044	V.R. or P.V.C.
above	60	up to and including	100	$^{5}/_{16}$ in. dia.	None
above	100	up to and including	150	$^{7}/_{16}$ in. dia.	None
above	150	up to and including	200	$^{1}/_{2}$ in. dia.	None

e) After the fuses have carried their rated currents continuously for sufficient time to allow their temperatures to become steady, the temperature-rises shall be in accordance with Clause **14**. No correction shall be made to the observed temperature-rises if the ambient temperature during the test is different from the assumed ambient temperature of 25 °C [see Sub-clause **14** c)].

NOTE 1 Satisfactory temperature-rise under the conditions specified in Sub-clause **21** a) implies a satisfactory temperature rise of the fuses without a case. Cases of different design and material from those used in the test may not necessarily be satisfactory.

NOTE 2 Base metal thermocouples attached by a tow-melting-point alloy of equal parts of lead, tin and bismuth are suitable.

22 High-voltage test: wet test for outdoor fuses

The fuse shall be mounted with its axis in either a horizontal or a vertical plane. In the absence of information on this point the fuse shall be tested with its axis vertical.

It shall be subjected to artificial rain in the form of a reasonably uniform, finely-divided spray falling on to it at an angle of approximately 45° to the vertical.

If the fuse is not in the vertical position the direction of the spray shall be at right angles to the horizontal projection of the axis, i.e. the spray shall not be directed along the axis of the fuse.

The fuse, previously washed clean and with 50 per cent of the test voltage applied to it, shall be sprayed for two minutes before application of the test voltage. The spraying shall be continued throughout the test.

The rate of precipitation shall be equivalent to 0.12 in. (3 mm) per minute. The rate shall be measured by means of a Meteorological Office rain gauge with its axis vertical, or by other suitable means. Individual measurements taken at the two ends and centre of the fuse shall not vary from the mean by more than 25 per cent and the mean rate shall not deviate from the required figure by more than 10 per cent.

The resistivity of the water conveyed to the spraying nozzles measured at the air temperature in the neighbourhood of the fuse shall be between 9 000 and 11 000 ohm-cm. The water shall be drawn from a source of supply at a temperature within 10 Centigrade degrees of the air temperature in the neighbourhood of the fuse.

A power-frequency test-voltage shall then be applied to the fuse as follows:

i) Between each pole or phase and earthed metal in turn, with the fuse-link in position and the remaining poles or phases of a polyphase assembly earthed, the fuses being mounted at the minimum spacing specified by the manufacturer.

ii) Between the terminals of a pole or phase with the fuse-link removed, or in the open position for fuses where the fuse-carrier remains attached to one set of fuse clips while providing an isolating gap.

During the test one terminal of the output of the source of test-voltage shall be connected to earth and to the portions of the fuse-mounts which are normally earthed in service.

Where the physical arrangement of one side of the fuse differs from that of the other side, test ii) above shall be made with each side of the fuse alive in turn.

The appropriate test voltage of Table 6, adjusted in accordance with Appendix J, shall be withstood for 30 seconds without flashover.

Table 6 — Power-frequency test-voltages for wet test on outdoor fuses

Voltage-rating	Test-voltage (withstand)
kV	kV
2.2	12
3.3	16
6.6	22
11	30
15	40
22	55
33	80
44	100
55	130
66	150
88	195
110	240
132	285

23 Impulse-voltage tests

Fuses, other than voltage-transformer fuses, for use on electrically exposed installations, shall be subjected to impulse-voltage tests. These tests will not be required for indoor fuses unless it is indicated at the time of the enquiry or order that they are for use on electrically exposed installations. (See Appendix H.)

Voltage-transformer fuses shall be subjected to the same impulse-voltage tests, if any, as the associated voltage-transformer.

For these tests the fuse shall be in clean new condition, and arcing-horns or rings may be removed or their spacing increased.

The test-voltage shall be a full impulse-voltage wave having a wave-front of 1 micro-second and a time to half-value of wave-tail of 50 micro-seconds, measurement of the wave-shape being made in accordance with BS 923 "*Impulse-voltage testing*".

The peak value of the test-voltages shall be not less than the value specified in Table 7 for the appropriate voltage-rating. These test-voltages may require correction for atmospheric conditions when they are applied to external insulation (see Appendix J.)

The test-voltage shall be applied to the fuse as follows:

i) Between each pole or phase and earthed metal in turn, with the fuse-link in position and the remaining poles or phases of a polyphase assembly earthed, the fuses being mounted at the minimum spacing specified by the manufacturer.

ii) Between the terminals of a pole or phase with the fuse-link removed, or in the open position for fuses where the fuse-carrier remains attached to one set of fuse clips while providing an isolating gap.

During the test one terminal of the output of the impulse-voltage generator shall be connected to earth and to the portions of the fuse-mounts which are normally earthed in service.

Where the physical arrangement of one side of the fuse differs from that of the other side, test ii) above shall be made with each side of the fuse alive in turn.

Five consecutive impulse-voltage waves shall be applied. If a flashover or puncture does not occur the fuse has passed the test. If puncture occurs or if two of the applied test waves cause flashover through air, the fuse has failed. If one of the applied test waves causes flashover through air, five additional test waves shall be applied. Only if puncture or flashover through air does not occur on any of these last five waves shall the fuse be considered to have passed the test.

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

The peak value and wave-shape of the test-voltage shall be recorded by means of a cathode-ray oscillogram of the voltage wave for the first and last wave applied in each group of five tests.

Table 7 — Impulse-voltage tests for electrically exposed fuses

Voltage-rating	Peak value of impulse test-voltage (withstand)	
	Non-effectively earthed systems	Effectively earthed systems
kV	kV	kV
2.2, 3.3	50	—
6.6	75	—
11	95	—
15	110	—
22	150	—
33	200	—
44	250	—
55	300	
66	350	—
88	450	380
110	550	450
132	650	550

24 Oil-penetration test for oil-tight cartridge fuse-links

The fuse-link shall be immersed in oil complying with the requirements of BS 148, "*Insulating oil (low viscosity type) for transformers and switchgear*" under a pressure of 10 lb/sq. in. The rated current of the fuse-link shall be passed through it for two hours 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 two-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 15 °C to 30 °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.

NOTE It is recommended that this test be repeated at regular intervals in order to check the uniformity of the product.

25 Sealing test for liquid fuse-links

The fuse-link shall be heated to a temperature of 75 °C to 85 °C or approximately 10 Centigrade degrees below the boiling point of the liquid filling, whichever is the lower figure; any leakage shall be detected by a suitable reagent.

NOTE 1 For chlorinated hydrocarbons a satisfactory test for detection of leakage consists of placing the fuse-link near a Bunsen burner flame impinging on a copper plate, when no change in colour of the flame should occur.

NOTE 2 It is recommended that this test be repeated at regular intervals in order to check the uniformity of the product.

26 Weatherproof test for powder-filled cartridge-fuses for outdoor use

Fuses, assembled as in service, with the fuse-link heated initially to a temperature of 75 °C to 85 °C shall be sprayed for 30 minutes with water at approximately the test room temperature at an angle of 45° to the vertical at a rate of 0.12 in. (3 mm) per minute. At the end of the test the fuse-link shall be dried externally and examined for cracking. If no cracking is visible the fuse-link shall be opened for inspection of the arc-quenching medium. If cracking is visible, or if the arc-quenching medium shows signs of ingress of moisture, the fuse shall be considered not to have passed the test.

NOTE It is recommended that this test be repeated at regular intervals in order to check the uniformity of the product.

27 Tests for breaking-capacity

Fuses shall be tested for breaking-capacity in accordance with Sub-clauses a) to l) below. The frequency of supply shall be rated frequency with a tolerance of ± 25 per cent.

a) *Arrangement of fuses for tests.*

i) Fuses to be tested shall be set up as complete units and shall truly represent their own type in all details of construction as recorded on certified drawings. They shall be mounted on their own supporting structure and within their own container, or equivalent when the use of their own container is impracticable. The fuses shall be complete with all barriers and clearances and the oil level (if any) shall be such as to simulate service conditions as closely as possible. All earthed metal parts, including the metal enclosures, if any, shall be earthed through a fine-wire fuse, wired with copper wire not greater than 0.0048 in. diameter (40 S.W.G.) and not less than 3 in. long, to detect leakage to earth during tests of the fuses.

If the operation of the fuse involves emission of flame, earthing the test circuit may affect its performance, and tests shall be made to prove that the fuse performance is satisfactory, irrespective of which terminal is connected to earth and which is connected to line.

In case of doubt on this point it may be necessary to make two series of tests as specified in Sub-clause **27** g) using alternative connections for line and earth, but where evidence is available as to which connection is the more onerous, then it shall be sufficient to test with that connection. The connections used shall be recorded in the report of type-tests.

ii) For fuses equipped with series current-limiting impedances, the impedance shall be connected to the live side of the test-circuit, and the value of this impedance shall be stated in the report of type tests. Adjustments to the value of the test-circuit impedance may be necessary to prevent the initial test-current value from exceeding the normal value experienced in service under fault conditions. The following adjustments shall be permissible:—

A. *Three-phase tests in accordance with* Figure 1(a). If the construction of the fuse is such that it is not possible to insert a link of negligible impedance without also by-passing its series current-limiting impedance it shall be permissible to insert in the linked pole a series current-limiting impedance equal in value to that normally included in the fuse.

B. *Single-phase test in accordance with* Figure 1(b) and Figure 1(c). It shall be permissible to insert an extra current-limiting impedance 73.2 per cent of the value of the impedance normally included with the fuse. This allows the total impedance value to be $\sqrt{3}$ times the normal value to compensate for the application of $\sqrt{3}$ times the normal voltage to neutral.

C. *Single-phase tests in accordance with* Figure 1(e). For pairs of fuses with current-limiting impedance for use in a single-phase circuit, it shall be permissible to insert an extra current-limiting impedance equal in value to that normally included with each fuse. Alternatively, the fuse-link of the second fuse may be replaced by a link of negligible impedance and its series current-limiting impedance shall be included in the circuit.

b) *Breaking-capacity*. The breaking-capacity performance of a fuse shall be stated as the prospective current in kilo-amperes that can be broken, the recovery-voltage of the test being in accordance with Sub-clause **27** l).

c) *Breaking-capacity rating*. The prospective current that can be broken by a fuse shall be stated as the average of the r.m.s. values of the alternating component of the prospective current measured in each phase at the instant corresponding to the severance of the fuse-element (see Appendix D).

d) *Applied voltage*. The applied voltage before short-circuit is the r.m.s. voltage applied to the test-circuit immediately before the test. The maximum and minimum values of applied voltage shall be respectively not more than 115 per cent and not less than 100 per cent of the voltage-rating of the fuse.

e) *Test-circuit power-factor*.

i) The power-factor of the circuit, excluding any current-limiting impedance used as a necessary adjunct to the fuse, shall be determined in accordance with Appendix E, and shall be the power-factor before fuse operation.For TEST DUTIES 1 and 2 of Sub-clause **27** g) the power-factor shall not exceed 0.15 lagging. For TEST DUTY 3 it shall not exceed 0.6 for voltages up to and including 11 kV; for higher voltages any convenient value of power-factor may be used.

ii) The power-factor of a polyphase circuit shall be considered to be the average of the cosines of the angles of lag obtained in all the phases.

iii) The power-factor of any phase shall not vary from the average by more than 25 per cent.

f) *Test-circuits*. A fuse shall be tested in the appropriate circuit as follows:—

i) *Three-phase systems*. Current-limiting fuses of all voltage ratings shall be tested in the circuit shown in Figure 1(b) or Figure 1(d), except that where the limitation of test plant prevents the use of this circuit, fuses of voltage ratings above 66 kV may be tested in the circuit shown in Figure 1(c).

Non-current-limiting fuses of all voltage ratings[3)], shall be tested in the circuit shown in Figure 1(a) except that, where the limitation of test plant prevents the use of this circuit, fuses of voltage ratings above 66 kV may be tested in the circuit shown in Figure 1(c).

ii) *Single-phase systems*. Fuses of all voltage-ratings intended for single-phase service shall be tested in either of the circuits shown in Figure 1(d) and Figure 1(e) appropriate to the type of fuse.

Where limitation of test plant prevents the use of the circuits shown in Figure 1(d) and Figure 1(e), fuses of voltage-ratings above 66 kV may be tested in the circuit shown in Figure 1(f).

g) *Standard type-test duties*. The standard type test shall consist of the following series of test duties. They shall be made with the fuse-element giving the highest current-rating assigned by the manufacturer for each physical size of fuse, and shall consist of the following series of test duties in a circuit arranged in accordance with Sub-clause **27** f).

Tests shall be made until three fuses are shown to have complied with the requirements of both TEST DUTY 1 and TEST DUTY 2.

For three-phase testing in the circuit shown in Figure 1(a), if the conditions are such that two fuses clear completely, before the phase containing the solid link makes circuit, the test is invalid.

For current-limiting fuses the tests in TEST DUTIES 1 and 2 shall be considered satisfactory only if arcing commences on an increasing test circuit voltage between the values of 50 and 100 per cent of the peak value of the applied voltage [see Figure 2 and Subclause **27** d)]:

i) Single-phase tests shall be considered satisfactory only if arcing commences on an increasing test-circuit voltage between the values of 50 and 100 per cent of the peak value of the applied voltage. [See Figure 2 and Sub-clause **27** d).]

ii) Three-phase tests shall be considered satisfactory only on those fuses in which arcing begins on an increasing test-circuit voltage between 50 and 100 per cent of the peak value of the applied voltage. [See Figure 2 and Sub-clause **27** d).]

TEST DUTY 1. Three tests shall be made in a circuit having a prospective current not less than the breaking-capacity rating of the fuse.

For voltage-transformer fuses rated above 750 MVA the breaking-capacity rating may exceed the output of the test plant. In such cases the fuse shall be tested at the highest available prospective current, and where the fuse employs a series current-limiting impedance the value of which is more than 100 times the impedance of the test-circuit, the test shall be deemed to prove the rating of the fuse (see Clause **1**).

[3)] Non-current-limiting fuses (e.g. liquid fuses, oil tank fuses and expulsion fuses) are required to be tested in a three-phase circuit because of the possibility of flame emission during short-circuit operation. It is, however, necessary to make an exception for voltage ratings above 66 kV where test plant is limited, as stated above.

TEST DUTY 2. *For current-limiting fuses.* If the cut-off current in TEST DUTY 1 is less than 70 per cent of the symmetrical peak current associated with the prospective current, three further tests shall be made at some smaller prospective current such that the cut-off current at this smaller prospective current is not less than 70 per cent of the symmetrical peak current associated with the smaller prospective current (see Figure 4 and Figure 5).

TEST DUTY 2. *For fuses other than current-limiting.* Three tests shall be made on fuses in a circuit having a prospective current of 30 per cent of the breaking-capacity rating of the fuse. The prospective current may depart from the specified value by ± 20 per cent of the specified value.

TEST DUTY 3. Two tests shall be made on fuses at a value of fusing-current which will sever the fuse-element in not less than 0.8 second. These tests shall be single-phase tests.

h) If there is another rating of fuse-element which, on any of the standard type-test duties would produce higher over-voltages than the fuse tested, the manufacturer shall satisfy the user, on request, that the fuse will comply with Sub-clause **28** a) ix).

j) For voltage-transformer fuses of the high impedance type, or those equipped with series current-limiting impedance, only TEST DUTY 1 need be performed, provided that the fuse impedance is more than 100 times the total circuit impedance for TEST DUTY 1. The prospective current shall be determined with the fuse and series current-limiting impedance replaced by a link of negligible impedance.

k) *Recovery-voltage.*

i) The recovery-voltage of the test-circuit shall always be stated in terms of a voltage between lines and may be referred to as a percentage of the voltage-rating.

ii) The initial recovery-voltage shall be not less than 100 per cent of the voltage-rating [see Sub-clause **27** d)]. The recovery-voltage shall be maintained across the fuse for not less than 15 seconds after the opening of the circuit by the fuse in order to indicate that the fuse will not fail under continued application of voltage, and the value shall not fall below 75 per cent of the voltage-rating.

iii) The recovery-voltage shall be measured across the terminals of every fuse as at V_r in Figure 1.

iv) The recovery-voltage at any test duty shall be the average of the values measured in all phases and shall be determined in accordance with Appendix F and Figure 3.

v) In order to obtain the recovery-voltages specified, the testing generator may have its excitation temporarily increased during the short-circuit period instead of, or in addition to, the initial over-excitation permitted by Sub-clause **27** d).

28 Criteria of failure in tests for breaking-capacity

a) *Behaviour of apparatus during tests.*

i) The apparatus shall not show undue distress when performing any test duty within its breaking-capacity rating.

ii) Oil-tank fuses, other than for use in the tank of a voltage-transformer, shall cause no emission of flame from the containing tank, and the gases produced, together with the oil displaced by the gases, shall be conducted from the tank and diverted from all exposed parts normally live. The amount of oil lost and the oil carbonization after each operation of a test duty shall be such as not to impair the satisfactory behaviour of the fuse during subsequent operations of the test duty or cause breakdown or significant electrical leakage.

iii) Fuses for use in the tank of a voltage-transformer shall not cause flame, oil or gas emission from the containing tank, and the carbonization after each operation shall be such as not to cause breakdown or significant electrical leakage.

iv) A powder-filled cartridge-fuse shall not emit flame or powder, except that a minor emission of flame from an indicating device is permissible, provided this does not contravene the criteria of failure in tests for duty in Sub-clause **28** a) vi).

v) For other types of fuses any emission of flame, gas or liquid shall not cause overheating or dangerous scattering of hot metal or other substances. The approximate length of the emission shall be recorded on the test report (see Appendix G).

vi) Any emission shall not cause breakdown or significant electrical leakage to earth or between poles nor shall it damage associated apparatus.

vii) The fine-wire fuse specified in Sub-clause **27** a) shall not operate.

viii) Where fuses are tested in pairs, neither fuse shall fail, irrespective of the instant of commencement of arcing.

ix) The peak value of the transient voltage which may be produced by the operation of a fuse shall not cause breakdown of a sphere gap, calibrated surge diverter or equivalent device, connected directly across the fuse, and including a current-limiting impedance, if any. The sphere-gap, calibrated surge diverter or equivalent device shall be set to spark over at the appropriate voltage specified in column 2 of Table 8. Any current-limiting impedance shall have a value in ohms not greater than 10 times the voltage-rating of the fuse, in kilovolts.

x) Fuses dependent for their correct operation on automatic movement of some component to provide an adequate insulating gap shall operate to produce this gap during the tests specified in Sub-clause **27** g).

Table 8 — Voltage settings in peak kV and r.m.s. kV of sphere-gap for checking transient voltage of fuse operation

Voltage-rating	Voltage settings at rated frequency	
r.m.s. kV	peak kV	r.m.s. kV
2.2	22	16
3.3	26	18
6.6	36	25
11	50	35
15	63	45
22	85	60
33	120	85
44	140	99
55	160	113
66	185	132
88	225	159
110	270	191
132	315	223

b) *Condition of apparatus after tests.*

i) After performing any test duty, as specified in Sub-clause **27** g), the mechanical parts and supporting insulators of the fuse shall be essentially in the same condition as before the test, and the fuse shall, without reconditioning, be capable of continuously withstanding a voltage equal to its voltage-rating without dielectric breakdown.

ii) The fuse-contacts and the fuse-mount shall not suffer such damage during the test as to render them unfit for further service without maintenance.

iii) A fuse-carrier shall remain intact after it has been extracted from the fixed contacts.

iv) For expulsion-fuses it is permissible, between type-test duties, to renew any parts which assist in arc-extinction.

v) Slight cracking of the cartridge of a non-rewirable cartridge-fuse is permissible provided that it remains otherwise intact after removal from its carrier and contacts. For rewirable cartridge-fuses there shall be no cracking of the cartridge.

vi) After the fuse-link has been renewed, the fuse shall be capable of carrying its rated current at rated voltage, operating at a fusing-current up to its breaking-capacity rating, and complying with this standard in all respects. For fuses where the fuse-element only is renewed, it is permissible to clean the fuse-element container before renewal of the fuse-element.

vii) The insulation resistance between terminals of the fuse shall be not less than two megohms for each kilovolt of the voltage-rating when measured with a 1 kV test set between 3 and 3½ minutes after the conclusion of the test.

An additional measurement shall be made not less than 15 minutes after the conclusion of the test, and the insulation resistance shall be not less than two megohms for each kilovolt of the voltage-rating of the fuse.

viii) Any tripping or indicating device shall have operated correctly.

Section 8. Routine tests

29 General

Routine tests as specified in Sub-clauses a) and b) shall be made on every fuse to prove compliance with the corresponding requirements of this standard and they may be made at any convenient ambient temperature.

a) *High-voltage tests at manufacturer's premises*. High-voltage tests shall be applied to fuses in clean new condition; the test-voltage (r.m.s.) shall be 2 kV + 2¼ times the voltage-rating.

The test-voltage shall be applied to the complete fuses between poles or phases, between poles or phases and earth, and across the terminals with the fuse-link or fuse-links removed, or in the isolated position where appropriate.

The test-voltage shall be alternating and of any available frequency between 25 and 100 cycles per second and approximately of sine-wave form.

The test-voltage shall be increased to full test-voltage as rapidly as is consistent with its value being indicated by the measuring instrument. The full test-voltage shall then be maintained for one minute. During the test, one pole of the testing transformer shall be connected to earth and to the earthed metalwork of the fuse.

The electric strength of some insulating materials decreases as the temperature increases, by an amount which may vary with the thickness and the form of the insulator. As a consequence the dielectric strength of the insulation may be lowest at the highest temperature that it will reach in service.

When the insulation is entirely of porcelain, the test may be made at 15 °C to 25 °C. When the insulation includes materials other than porcelain, the test may be made at a temperature of 15 °C to 25 °C, provided that the manufacturer satisfies the purchaser by means of a type test that individual sections of the insulation will withstand the test-voltage at the maximum temperature that may be reached in service.

b) *High-voltage tests after erection on site*.

i) After erection on site, and if specified by the purchaser, the fuse shall be tested at a voltage (r.m.s.) of 2 kV + twice the voltage-rating of the fuse, for one minute; the test-voltage shall be alternating, of any frequency between 25 and 100 cycles per second, of approximately sine-wave form, and shall be applied as in Sub-clause a) above.

ii) If a test of longer duration than one minute is required the test-voltage shall be reduced in accordance with Table 9.

Table 9 — Test-voltages in tests of longer duration than one minute

Duration of test	Percentage of 1-minute test-voltage
minutes	
1	100
2	83.5
3	75
4	70
5	66.6
10	60
15	57.7

Appendix A Notes on terms used in the standard relating to performance of fuses

The various types of fuses to which this standard may be applied are described in the Scope and Definitions. Not only may these different types have widely differing performance characteristics but fuses of the same type may also have differing characteristics depending on their design. The following notes are included in amplification of the definitions relating to performance of fuses.

1. Fuse. The term "fuse" as applied to a protective device should by definition be taken as applying to the device as a whole, and not to any of its individual parts (a fuse-link, for example, is often incorrectly called a "fuse").

2. Rated current and fusing-current.

a) *Rated current;* this is the current which a fuse will carry *continuously* without deterioration and the term is synonymous with the term "*current-rating*". If a fuse is required to carry, for any long period, a current greater than its rated current, deterioration of the fuse may occur, resulting in unwanted or incorrect operation later. Temperature-rises may also be greater than those permitted in the standard, which are based on the fuse carrying rated current and not over-current.

b) *Fusing-current;* this is the current at which the fuse-element will melt; it varies inversely with time. It is the purpose of the characteristic curves supplied by the manufacturer to represent this current plotted against time.

3. Time/current characteristic. The time/current characteristic of a fuse, illustrated in Figure 6(*a*) is usually required when selecting fuses (see Appendix B). In the determination of such characteristics, the fuses usually start from a temperature not greater than 25 °C and usually have not carried current before the test. The times plotted for the characteristics are the pre-arcing-times, and when a fuse that has been carrying a load current for some time operates at some greater current, the pre-arcing-time is in general less than that shown by the time/current characteristic. The fusing-currents may be symmetrical or asymmetrical and produce different curves for times less than about 0.1 second. This difficulty is avoided by plotting curves on the basis of virtual time (see Appendix K.)

In a three-phase fault the currents in at least two phases will usually exhibit some degree of asymmetry, depending on the power-factor of the circuit.

The current-asymptote of the time/current characteristic is termed the minimum fusing-current, and the ratio of this current to the rated current is termed the fusing-factor.

4. Pre-arcing-time, arcing-time and total operating-time. These times vary with the value of prospective current as indicated in Figure 6 and Figure 10. The arcing-time usually becomes a greater proportion of the total operating-time as the prospective current increases. This fact is important when considering discrimination. (See Appendix B.)

5. Prospective current, cut-off and current-limiting fuse. Owing to the current-limiting characteristics of certain types of fuse, it has become necessary to introduce the terms "prospective current", "cut-off", and "current-limiting fuse". In general, current-limitation is exhibited by powder-filled cartridge-fuses but not by liquid, expulsion and oil-tank fuses.

Although it is true that the impedance of a fuse may reduce the maximum possible current in a circuit to a value somewhat less than that of the maximum prospective current of the circuit, the limitation of current from this cause is not what is understood by cut-off. Cut-off is the result of current-limitation by high arc-voltage and occurs only if the fuse-element melts prior to the prospective current peak. Prospective current is sometimes confused with short-circuit current, but short-circuit current as commonly understood is one particular value of the prospective current of a circuit, namely the maximum. Some fuses would cut off only at currents greater than their breaking-capacity rating, and no fuse cuts off at all prospective currents. Figure 5 shows a typical oscillogram where, with a large prospective current, cut-off occurs. For current-limiting fuses with small prospective currents the operation becomes similar to those of non-current-limiting fuses, in that the peak value of the arc-voltage is less than the peak value of the recovery-voltage, and arcing may thus be prolonged over several half cycles.

In an a.c. circuit, the prospective current is defined as the r.m.s. value of the alternating component of the current that flows in a prospective current test, because the alternating component alone affords the possibility of a common term of reference. The actual form of the current as a whole depends on the power-factor of the circuit and the point on the voltage wave at which the circuit is made; i.e. there are varying degrees of asymmetry, implying that the first major loop of current may have a peak value anywhere between i and $2i$, where i is the peak current corresponding to the (r.m.s.) prospective current. For this reason, and to avoid complication of statement, the definition (as Definition **3.22**) is adopted, although the cut-off current may, in fact, sometimes be *numerically* greater than the prospective current, which is expressed as an r.m.s. value.

6. Operation. Operation includes all that happens in a fuse during both pre-arcing-time and arcing-time. The term "melting" (or "fusing") is sometimes used in the sense of operation as defined; but "melting" (or "fusing") can only be properly used to describe what happens in a fuse during a part of the pre-arcing-time. Since it is the duty of a fuse to operate satisfactorily at *all* prospective fusing-currents up to its breaking-capacity rating, the tests specified in Sub-clause **27** g) have been chosen to ensure as far as possible that standard fuses are capable of doing this.

7. Arc-voltage. With powder-filled cartridge-fuses the peak value of the arc-voltage may exceed the peak value of the rated-voltage.

In order to prove that standard fuses will not produce dangerous over-voltages from the above cause, the connection of a sphere-gap, calibrated surge diverter, or equivalent device, across the fuse during tests is specified in Clause **28**, and Table 8 gives the voltage setting related to rated voltage for such devices. During short-circuit tests the arc-voltage should not break down the sphere-gap or diverter.

Appendix B Selection of fuses

1. General. The selection of suitably rated fuses for a given duty in service should be made by considering the technical factors set out below. Haphazard selection leads to unsatisfactory behaviour of fuses as protective devices and special care should be taken to ensure a good choice; a choice preferably taken in collaboration with the manufacturer.

Care should be taken in selecting fuses for particular situations; for example, liquid-fuses should not be used indoors.

Whether or not a fuse is capable of affording satisfactory over-current protection depends on the relation between the minimum fusing-current and the anticipated over-current. In general, fuses are recommended for short-circuit protection only, but where the over-current corresponds to a pre-arcing-time of less than 0.8 seconds, the breaking performance of the fuse will be satisfactory.

2. Service conditions. See Section 4.

3. Circuits to be protected. Circuits to be protected may be divided into two general classes:

a) *Steady-load circuits.*

Circuits with loads which do not fluctuate much above normal value may be called "steady-load" circuits.

If, as often happens, fuses are the only protection in a steady-load circuit, their rated current should be the standard equal to or next greater than that of the circuit or of the apparatus, whichever is smaller. If other over-current protection is provided, or if discrimination requires it, a fuse of still greater rated current may be permissible or necessary.

b) *Fluctuating-load circuits.*

Circuits with loads which may fluctuate to peaks of comparatively short duration above normal value, e.g. motor circuits, capacitor circuits and transformer circuits, all of which are subject to a switching transient over-current, may be called "fluctuating-load circuits".

For fluctuating-load circuits the fuses should have time/current characteristics such as to allow the transient over-current to be carried without operation. For this purpose it may sometimes be necessary to select fuses of a rated current greater than that of the circuit.

i) *Motor circuits*. Fuses for service on motor circuits should be carefully selected to ensure freedom from unwanted operation on starting and, at the same time, to avoid deterioration due to frequent starts with currents greater than the rated current of the fuse but less than the fusing-current corresponding to the duration of the switching-in peak.

Table 10 may be used as a guide in selecting fuses for motor-starting duty where the starting time does not exceed 30 seconds; e.g. for fans and blowers. For drives with extra heavy inertia or where very frequent starting is necessary, the fuse manufacturer should be consulted. [See also **5** b) ii) below].

Table 10

Rated current of fuse	Type of motor and starter		
	Squirrel-cage motor		**Slip-ring motor**
	Direct-on-line starter	**Star-delta or auto-transformer starter**	**Resistance starter**
	Standstill current not in excess of	**Standstill current not in excess of**	**Full load current not in excess of**
amp.	amp.	amp.	amp.
10	16.5	22.5	4.5
20	33	46	9.1
30	50	69	14
40	67	92	18.5
50	82	112	22
60	103	142	28
75	134	187	38
100	185	255	51
150	370	510	102
200	525	725	145

ii) *Capacitor circuits*. It is essential that fuses shall not be blown by the inrush current which flows when a capacitor is switched in. It is accordingly desirable to obtain a definite recommendation from the fuse manufacturer as to the current-rating of the fuse. As a guide, a fuse having a rating of 150 per cent of that of the capacitor has frequently been found suitable.

iii) *Transformer circuits*. The following factors, where appropriate, should be taken into consideration in choosing the current-rating of the fuse in the primary circuits of transformers (see also Figure 6). In case of doubt, the fuse manufacturer should be consulted.

A. Inrush current. This current, as a proportion of full-load current, tends to decrease with increase in transformer rating.

B. Overload currents to be carried by the transformer.

C. Discrimination with fuses or relays in the secondary circuit, bearing in mind that such protection is usually required to operate without blowing the primary fuse.

D. The desirability, on overhead systems, of reducing the risk of fuses being blown as a result of lightning over-voltages.

4. Short-circuit rating. A knowledge of the values of short-circuit current to be expected at the point of application is essential when selecting fuses. This is considered in Appendix C.

5. Discrimination. The following paragraphs set out the principles on which correct discrimination in operation, a), between fuses and fuses, or b), between fuses and other over-current protective devices, depends. In view of the many variables involved in predicting discrimination it is recommended that the assistance of the manufacturer should be sought in the form of specific information on discrimination.

a) *Between fuses and fuses.* Discrimination occurs when the fuse or fuses nearest to a fault operate, leaving all other fuses in the circuit unimpaired. Since discrimination is required at any current within the breaking-capacity rating of all the fuses concerned, it is necessary that the time/current characteristic of any fuse A must lie, throughout its length, below that of any fuse B nearer to the supply point, as shown in Figure 6(*a*). Where fuses are used on the primary and secondary sides of a transformer, the current ratio should be taken into account.

Discrimination can be relied upon under these conditions, however, only when the arcing-time of fuse A is small compared with its pre-arcing-time.

The first important factor for discrimination is pre-arcing-time; in the second place it must be noted that an alteration in the temperature of the fuses gives them time/current characteristics different from the type-test values; and in the third place it must also be noted that the time/current characteristics may differ from the type-test values according to circuit conditions (e.g. asymmetry and power-factor) at the time of operation.

On short-circuit, since the pre-arcing-time is short and the time/current characteristics are based on pre-arcing-times, discrimination cannot be predicted from time/current characteristics. This is because the arcing-time becomes a higher proportion of the total operating-time, with the result that the current during the arcing-time of the smaller fuse may cause the larger fuse to operate. Where adequate information on arcing-time is available, it may be used to prepare curves of virtual total operating-time to assist in predicting discrimination.

Figure 6(*b*) shows generally the difference in form between the time/current characteristics of liquid-fuses or expulsion-fuses and those of some cartridge-fuses, and when those apply, a wide divergence of current-rating is necessary. The characteristics of the fuses selected should be widely separated at small currents, in order that they shall not cross at large currents.

b) *Between fuses and other over-current protective devices.*

i) *General.* The general use of fuses with other over-current protective devices is for back-up protection; that is to say, the other device is required to clear the lower values of fault-current through the normal operation of its automatic trips, and only at currents above some predetermined value is the fuse required to take over the protection of the circuit. It is therefore necessary that the time/current characteristics of the fuse and of the other devices shall cross at the desired value of current. This promotes continuity of supply by allowing operation of the fuses only with electrical faults, and minimizes the possibility in three-phase circuits of single-phasing, such as may be caused by the operation of a fuse in one phase only.

Figure 6(*c*) shows a typical time/current characteristic for a fuse and some other device, T being the take-over point. At currents above T there remains the possibility that although the fuse interrupts the circuit, the current it passes may, by its magnetic or thermal effects, damage the other device; therefore, quite apart from any question of breaking-capacity, the back-up fuses should have a small cut-off current. It is desirable that the other device should have an adequate straight-through fault-current rating.

The take-over point should be at a current slightly less than the breaking-capacity of the other device, but to avoid unnecessary operation of the fuses by any currents that can be safely interrupted by the other device it is necessary to ensure that the take-over point is not unduly low.

In addition, the maximum cut-off current of the fuse, whether under symmetrical or asymmetrical conditions, must be within the making-capacity of the other device. To ensure this it may be necessary to use a fuse of lower current-rating than would be required by other considerations.

ii) *Motor-starter circuits.* The breaking-capacity of a motor starter usually does not greatly exceed the starting-current of the motor. The fuse should therefore be of the smallest current-rating that will carry the starting-current for the time of the start with the requisite margin. This method of selection ensures that the fuse can never operate except under electrical or maximum mechanical fault-conditions, and at the same time gives the lowest possible value of take-over current, so minimizing possible damage to the motor-starter.

6. Statutory requirements. On premises subject to the Factories Act, 1937, the Electricity Regulations — Statutory Rules and Orders No. 1312 dated 1908, and No. 739 dated 1944, apply.

Appendix C Calculation of short-circuit fault-currents

BS 116:1952[4)], Appendix C, deals adequately with the factors which control, and the method of calculating, the values of short-circuit current which can flow through a fuse under various conditions of service. They are not therefore repeated here, and reference to BS 116 is recommended.

It may be reiterated that in order to calculate accurately the value of short-circuit current at any given point, it is essential that the fullest information be available, preferably in the form of a network line diagram, stating the number, MVA ratings, reactance, resistance, arrangement and voltage of all generators, transformers, reactors, cables, overhead lines and system connections through which power can be supplied.

It is important to note that the resistance of alternators, transformers and reactors is generally negligible compared with their reactance and can be ignored in short-circuit calculation; the resistance of cables and overhead lines is often considerable, particularly where the current-carrying capacity is small, and must then be taken into account.

The requirements of the Electricity Regulations, insofar as breaking capacity under short-circuit conditions are concerned, are referred to under Appendix B.

Appendix D Measurement of prospective current and cut-off current

Prospective current is measured in a test (made as a preliminary to a test for breaking-capacity) for which a link of negligible impedance is used in place of the fuse.

In an a.c. circuit, current is usually measured as the r.m.s. value of the symmetrical constant-amplitude wave-form it reaches shortly after the circuit is made. The time between the making of the circuit and the reaching of the measured value depends on the time-constant of the d.c. component of the transient asymmetrical current.

The initial magnitude of the d.c. component (or the degree of asymmetry) in any circuit is dependent on the point on the voltage-wave at which the circuit is made, and the rate at which the d.c. component falls from its initial magnitude is dependent on the power-factor of the circuit.

If the required current is large it is usually not possible to obtain a constant-amplitude wave-form in an a.c. prospective-current test, because of characteristics inherent in the source of power for the test or because of limitations imposed on the operation of large-current a.c. testing-equipment. In these circumstances the prospective current is measured as the r.m.s. value of the alternating component of the current over a stated period of time; the arbitrary period usually taken is the first 0.01 second after the making of the circuit. In practice it is usually sufficiently accurate to make this measurement in the way indicated in the next paragraph.

An oscillogram of the current is taken, and from this oscillogram (see Figure 4):

1) AA_1 and BB_1 are drawn as the envelope of the current-wave.

2) The point O, corresponding to the instant when the circuit is made, is marked and the current zero-line is produced from O to F, where F corresponds to a time 0.01 second after O.

3) GH is drawn through F perpendicular to the current zero-line to intersect AA_1 and BB_1 at G and H respectively.

The prospective current during the first 0.01 second after the making of the circuit is deemed to be given by $GH/2\sqrt{2}$.

If cut-off occurs in a test for breaking-capacity, a constant-amplitude wave-form is not reached (see Figure 5). It is therefore difficult to refer to cut-off current in terms of an r.m.s. value, and cut-off current is measured as the *instantaneous* value of the maximum current reached when a fuse cuts off.

Because prospective current is expressed as an r.m.s. value and cut-off current as an instantaneous value, a cut-off current value may exceed the prospective current value.

[4)] BS 116, "*Oil circuit-breakers for alternating current systems*".

Appendix E Measurement of power-factor

Power-factor may be measured by the following methods:

1. From circuit constants (before test). The power-factor may be determined from the cosine of an impedance angle ϕ where $\phi = \arctan \frac{X}{R}$ and X and R are respectively the reactance and the resistance of the test-circuit.

2. From oscillograms.

i) If there is sufficient asymmetry of the prospective current the angle ϕ may be determined from the curve of the d.c. component of the asymmetrical current-wave, as follows:

Determine the time constant $\frac{L}{R}$ of the d.c. component. The d.c. component has the general form of

$i_d = I_{do}\, e^{-Rt/L}$ (See Figure 4.)

where i_d = the value of the d.c. component at any instant.

I_{do} = the initial value of the d.c. component, at the instant of short-circuit.

$\frac{L}{R}$ = the time-constant in seconds of the test circuit.

t = the time-interval in seconds between the instant at which I_{do} is measured and the instant at which i_d is measured.

e = the base of Naperian logarithms.

The time-constant $\frac{L}{R}$ scan be readily determined from this formula as follows:

a) Measure the value of I_{do} at the instant of short-circuit and the value of i_d at any other instant t.

b) Determine the value of $e^{-Rt/L}$ by dividing i_d by I_{do}.

c) From a table of e^{-x} determine the value of the index ($-x$) corresponding to the ratio $\frac{i_d}{I_{do}}$

(The value of e^{-x} can be obtained readily from a table of Naperian logarithms by taking the reciprocal of the number of which x is the logarithm.)

d) The value x represents $\frac{Rt}{L}$, from which $\frac{L}{R}$ can be determined by dividing t by x.

Determine the angle ϕ from

$$\phi = \arctan \frac{\omega L}{R}$$

where ω is the actual frequency multiplied by 2π

ii) For the higher values of power-factor in this standard, asymmetry is likely to be insufficient for an accurate determination of $\frac{L}{R}$, and this alternative method should then be used; it requires a voltage-trace in addition to a current-trace, as shown in Figure 7. The part of the current-wave at which the asymmetry, if any, has disappeared is determined by comparison of the duration of the current-loops. Thus asymmetry has disappeared at A since AB = BC. A distance AD is then measured backwards along the current-zero, making AD equal to AB; it may be necessary to measure more than one such distance. A projection E on the current-zero is then made from the point F, which represents the last voltage-zero before short-circuit application.

Then ED, to the appropriate scale, is the angle ϕ, and the power-factor is cos ϕ.

Appendix F Measurement of recovery-voltage

The recovery-voltage between lines [see Sub-clause **27** l) iii)] is measured in accordance with Figure 3 as follows:—

1) Draw on the oscillogram a straight line between the first and third peaks of the recovery-voltage after the instant of final arc-extinction;

2) Measure the length of the vertical line between this straight line and the intermediate peak, and

3) Multiply this length by the appropriate calibration constant and divide the value of voltage so ascertained by $2\sqrt{2}$.

Figure 3 illustrates how the above method of measuring a recovery-voltage wave is applied to the particular case of two recovery-voltage components obtained during a test upon a three-phase group of fuses in a three-phase test circuit having one of the fuses replaced by a link of negligible impedance to ensure full line voltage across the two fuses under test.

Appendix G Example of data to be included in a report of type-tests for breaking-capacity

Date of tests.

Reference or report number.

Apparatus tested.

Type or list number

Description

Manufacturer

Photograph numbers

Drawing numbers

Ratings assigned by manufacturer

Voltage-rating in kV

Rated current in amperes

Frequency in cycles per second

Number of phases

Breaking-capacity in r.m.s. kA symmetrical at voltage-rating in kV (equivalent to ...MVA...phase).

Test conditions

Number of phases

Power-factor

Number of poles

Frequency in cycles per second

Generator neutral (earthed or insulated)

Transformer neutral (earthed or insulated)

Short-circuit point (earthed or insulated)

Frame of fuse (earthed through a fine-wire fuse)

Diagram of connections

Voltage setting of shunt spark-gap, calibrated surge diverter, or equivalent device

Specification

Test made in accordance with BS 2692

Record of proving tests

1. Test number
2. Oscillogram number

Severity of test-circuit

3. Applied voltage in kV
4. Prospective current in r.m.s. kA
5. Power-factor

Performance on test

Current kA

6. First major peak or cut-off value

Current broken r.m.s.

7. Phase values
8. Average value

Recovery-voltage

9. Phase values in kV
10. Average value in kV
11. Percentage of voltage-rating

Pre-arcing-time

12. In hundredths of a second

Arcing-time

13. In hundredths of a second
14. Loops

Total operating-time

15. In hundredths of a second

Shunt spark-gap operation

16. Device operated, or not

Physical condition and behaviour

17. Condition before test
18. Behaviour during test (including length of flame emission, if any)
19. Condition after test
20. Condition of fine-wire fuse
21. General observations

Appendix H Insulation co-ordination

There are two broad classifications of fusegear construction; namely, indoor and outdoor. It is also necessary to recognize two separate electrical conditions under which the insulation of equipment may be required to operate. These conditions can be described as "electrically non-exposed" and "electrically exposed". (See Definitions **3.38** and **3.39**.)

Outdoor fusegear is generally associated with overhead transmission lines, and is therefore subjected to over-voltages of atmospheric origin caused by lightning strokes. Such over-voltages may cause much greater stress in the insulation than the internal over-voltages which can be caused by the switching of the system. Suitable impulse-voltage tests have therefore been specified for fuses in electrically exposed installations.

It is desirable that the amplitude of surges imposed on the terminals of electrically exposed fuses should be limited to a value less than that of the impulse-test level, and it is recommended that suitable protective devices be installed for this purpose.

Most indoor apparatus is intended for voltage-ratings not exceeding 33 kV, is used on systems employing cables throughout the network, and is thus protected from over-voltages due to lightning. The internal over-voltages on such systems are generally less than the insulation level of standard fuses for electrically non-exposed installations. Furthermore, existing designs of such fuses have given satisfactory service on cable systems; accordingly impulse-voltage tests for such fuses are not specified.

Appendix J Correction-factors for atmospheric conditions during impulse-voltage tests, and for air density during wet withstand voltage tests

Variations in barometric pressure and in humidity of the atmosphere cause variation in the electric strength of the air and hence also in the flashover voltage of insulators exposed to the air; puncture strength, however, is not affected by these changes.

In general, day-to-day differences in the atmosphere of a test room are not significant, but occasionally it may be necessary to make adjustments to the impulse test-voltage which will give the equivalent of the standard impulse test-voltage as far as air flashover is concerned, when applied under standard atmospheric conditions. The test procedure under these circumstances should be as follows:

a) Impulse waves of the polarity (usually negative) giving the higher air flashover voltage should be applied at the specified test-voltages to test the internal insulation.

b) Impulse waves of the polarity giving the lower air flashover voltage should be applied at a reduced voltage (in accordance with the correction given below) to test the external insulation.

The standard atmospheric conditions are as follows:

Temperature	20 °C
Pressure	760 mm Hg
Humidity	11 g of water per cubic metre (4.8 grains per cubic foot) of air

The air-density correction-factor *d* is given by the expression:

$$d = \frac{0.386b}{273 + t}$$

where b = barometric pressure in millimetres of mercury

t = temperature in degrees Centigrade

(For a nomogram connecting *d, t,* and *b*, see Figure 8.)

The humidity correction-factor may be read from the curves in Figure 9.

For other than standard atmospheric conditions, the correction for the test-voltage in *b*) above should be obtained by multiplying the value specified in Table 7 by the air-density correction-factor and dividing by the humidity correction-factor.

The corrected value for wet withstand tests is obtained by multiplying the specified test-voltage in Clause **22** by the air-density correction-factor.

Appendix K Virtual time

General. The characteristics of fuses, when operating in short times, are important in connection with the use of fuses for limiting the destructive effect of heavy faults and in connection with discrimination with other fuses. In both instances, the determining factor is usually the time integral of the square of the current actually passed by the fuse, equal to $\int i^2 dt$, the integration being over either the pre-arcing period or the total operating period.

Virtual Pre-arcing-time. If the actual pre-arcing-time of a fuse is plotted against prospective current, a very considerable spread is observed for times less than about 0.05 seconds; it is caused principally by variations in the point on the voltage-wave at which the circuit is closed. On the other hand, $\int i^2 dt$ for the pre-arcing period is sensibly constant for these short times, since heat dissipation from the fuse-elements is very small. This constancy of $\int i^2 dt$ means that variations in pre-arcing-time do not represent a corresponding uncertainty in protection or discrimination. It is thus desirable to eliminate variations in the pre-arcing-time/current characteristics by plotting against prospective current a time equal to

$$\frac{\int i^2 dt \text{ for the pre-arcing period}}{I_p^2}$$

i.e. the virtual pre-arcing-time as given in Definition **3.32**. For times less than about 0.01 to 0.1 second (depending on the design of the fuse) the resulting curve when plotted with logarithmic co-ordinates, time being the ordinate, is a straight line having a slope of 2 to 1, as shown in Figure 10. It coincides with that which would be obtained by testing under the ideal condition of a d.c. circuit of zero inductance, and plotting actual time against actual current or prospective current, these two values of current necessarily here being the same.

For times greater than about 0.1 second, the difference between actual time and virtual time is very small and consequently curves of actual time and virtual time coincide in this region.

Virtual total operating-time. The information regarding arcing-time called for in Clause **12** is conveniently given by plotting virtual total operating-time against prospective current on the same sheet as the curve for virtual pre-arcing-time; the vertical distance between the two curves gives virtual arcing-time. An example is given in Figure 10.

The heating effect of the actual current passed by the fuse is obtained by multiplying the virtual total operating-time by the square of the prospective current, and this i^2t value may be compared with known i^2t values for cables and other apparatus, corresponding to their short-time thermal rating.

For discrimination between two fuses to be obtained, the virtual pre-arcing-time of the fuse nearer to the point of the supply must exceed the virtual total operating-time of the other fuse. Thus a comparison of the virtual time curves for the two fuses will show immediately whether discrimination is likely.

Measurement of virtual time. Two methods are available.

a) *From oscillograms.* The values of $\int i^2 dt$ for the pre-arcing period and for the arcing period (see Figure 11) are determined by drawing ordinates at equal intervals of time for the two periods. Sufficient accuracy is usually obtained by the use of six such intervals, as shown in Figure 11.

The following symbols are used:

t_p = actual pre-arcing-time.

t_{vp} = virtual pre-arcing-time.

t_a = actual arcing-time.

t_{va} = virtual arcing-time.

i (with numerical suffix) = current at instant corresponding to suffix.

I_p = prospective current.

Then t_{vp} is given by:

$$\left[\frac{4\,(i_1^2 + i_3^2 + i_5^2) + 2\,(i_2^2 + i_4^2) + i_6^2}{18\,I_p^2}\right] t_p$$

and t_{va} is given by:—

$$\left[\frac{i_6^2 + 4\,(i_7^2 + i_9^2 + i_{11}^2) + 2\,(i_8^2 + i_{10}^2)}{18\,I_p^2}\right] t_a$$

Alternatively, curves of i^2 may be drawn and $\int i^2 dt$ determined from the curves by measuring the area beneath them by planimeter or otherwise.

If the rise of current during the pre-arcing period is seen from the oscillogram to be substantially linear, then the virtual pre-arcing-time can be computed from:—

$$t_{vp} = \frac{(\text{Current at end of pre-arcing period})^2 t_p}{3\,I_p^2}$$

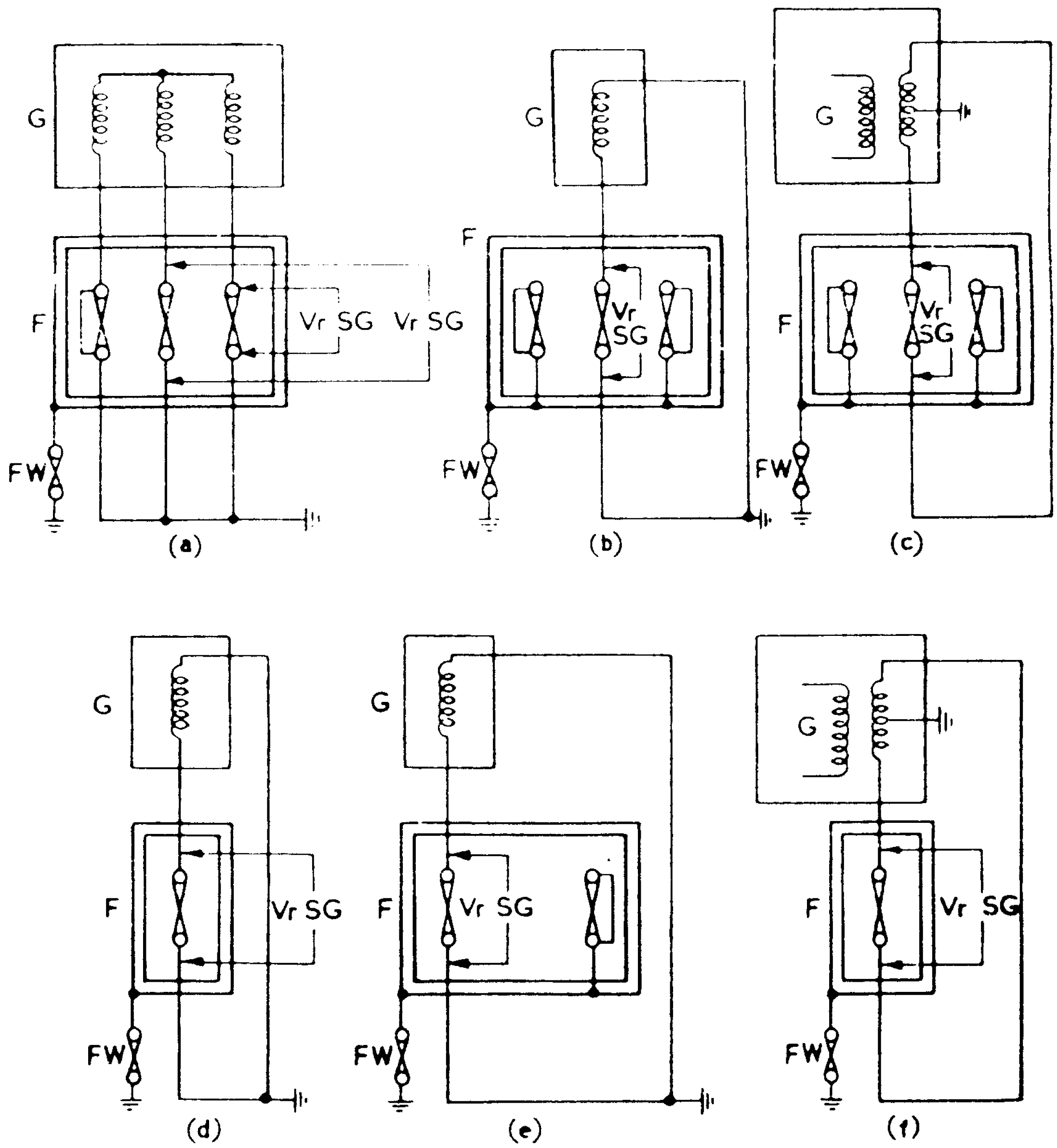
b) *By the use of instruments connected to the test-circuit.*

The virtual total operating-time may be obtained by determining the value of $\int i^2 dt$ by means of an electrodynamic instrument with ballistic characteristics or an instrument with thermal converter, the instrument in each case being fed from a shunt in series with the fuse.

Preparation of Curves from Virtual Time Measurements. *Pre-arcing-time.* Since for times less than about 0.01 to 0.1 second the $\int i^2 dt$ value for the pre-arcing period is constant, the curve can be drawn accurately from one or two tests at such values of time [usually from type-test duties 1 and 2 of Sub-clause **27** g).] bearing in mind that the slope in this region is 2 to 1 (for logarithmic co-ordinates, time plotted as ordinate).

Arcing-time. The arcing-time at any particular value of prospective current is subject to appreciable fortuitous variations and to considerable variations dependent on recovery-voltage and power-factor, and, particularly for current-limiting fuses, on the point on the voltage-wave at which the fault occurs. It is therefore desirable to plot points from all the available oscillograms. Unlike the pre-arcing-time curve, which is plotted to show mean values, a curve of arcing-time should be drawn to represent maximum values, bearing in mind that for all types of fuse the values of recovery-voltage and power-factor stipulated in Sub-clauses **27** l) and **27** e) respectively are such as to result in values approaching the maximum, while for current-limiting fuses the conditions regarding commencement of arcing stipulated in Sub-clause **27** g) are also such as to result in values approaching the maximum.

For arcing-time, it is usually not possible to work to a tolerance on current as close as the figure of ± 20 per cent of the current stipulated in Clause **12** for pre-arcing-time, and this fact should be borne in mind in applying the information given in curves of arcing-time.



F = Fuse under test.

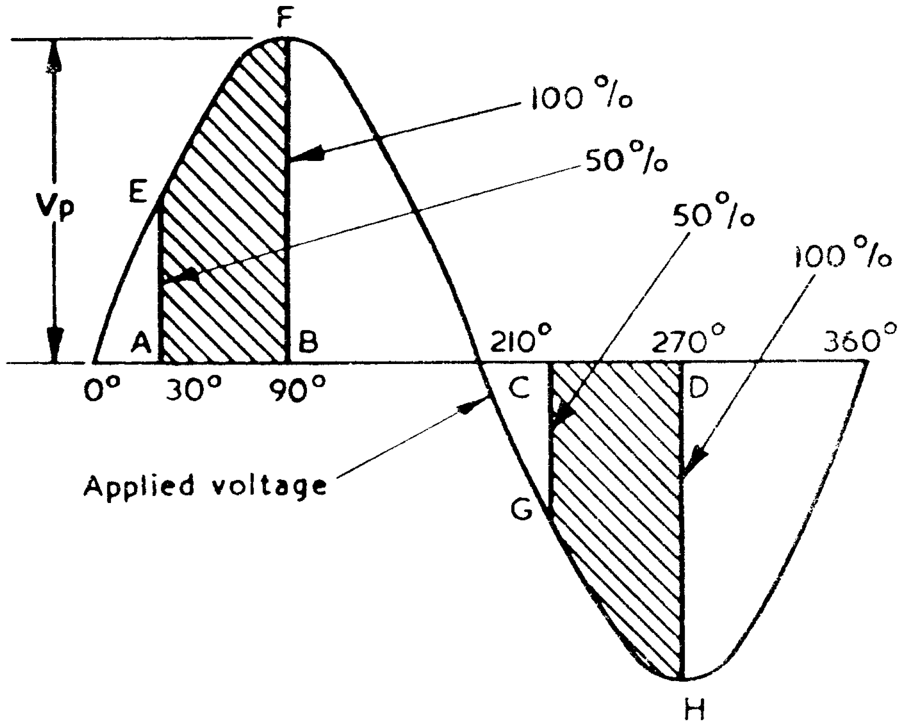
FW = Fine-wire fuse.

G = Generator or transformer together with any necessary external impedance. The windings shown do not necessarily represent the actual windings employed in the source of power.

Vr = Recovery-voltage.

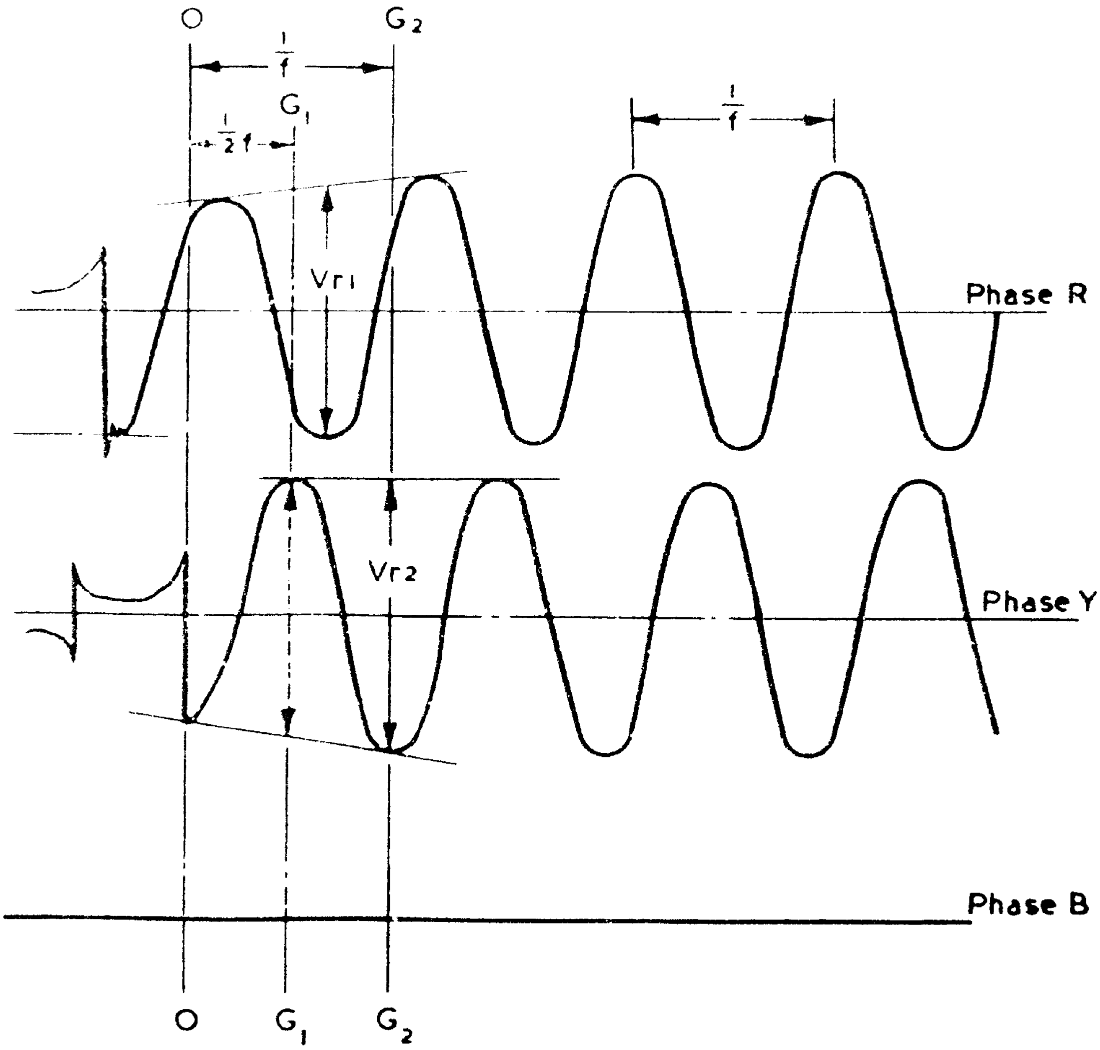
SG = Position of connection of sphere gap.

Figure 1 — Test-circuits and voltages



The start of arcing to be in the shaded time bands (see Clause **27**).
Voltage increasing from 0.5 Vp to Vp, i.e. from AE to BF or from CG to DH
Vp = Peak voltage across one pole.

Figure 2 — Test for current-limiting fuses



Phase R = First to open circuit.

OO = Instant of final arc-extinction.

G_1G_1 = Instant $\frac{1}{2f}$ from OO.

G_2G_2 = Instant $\frac{1}{f}$ from OO.

f = System frequency in cycles per second.

$\frac{Vr_1}{2\sqrt{2}}$ = Recovery-voltage phase R.

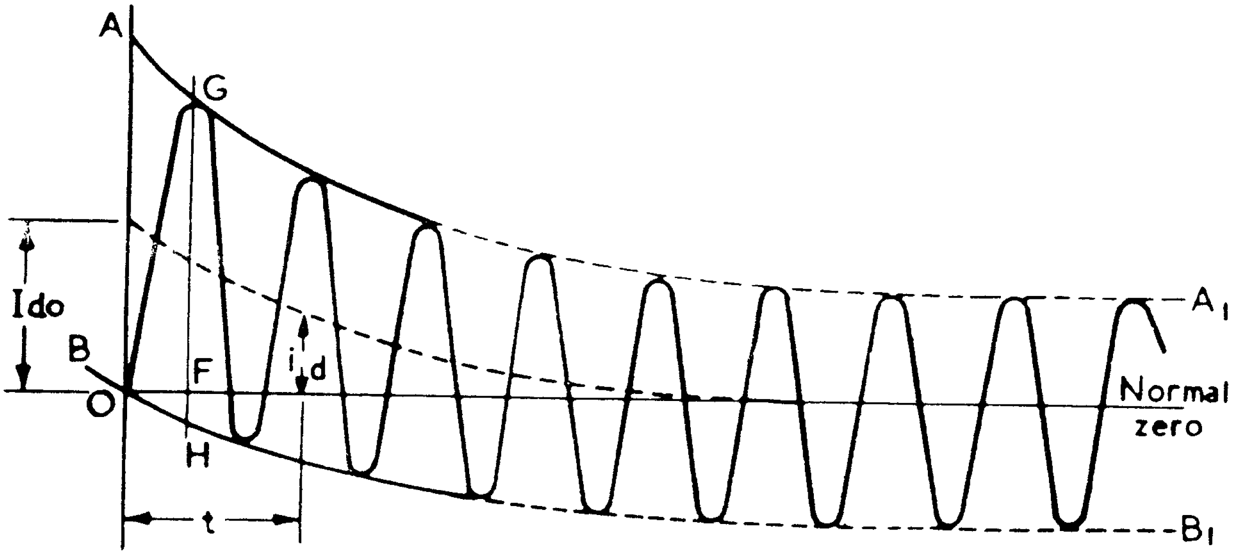
$\frac{Vr_2}{2\sqrt{2}}$ = Recovery-voltage phase Y.

$$\text{Average recovery-voltage} = \tfrac{1}{2}\left(\frac{Vr_1}{2\sqrt{2}} + \frac{Vr_2}{2\sqrt{2}}\right)$$

NOTE 1 In phase Y a voltage peak occurs exactly at interval G_1G_1. In such event measurement is made at the later interval G_2G_2.

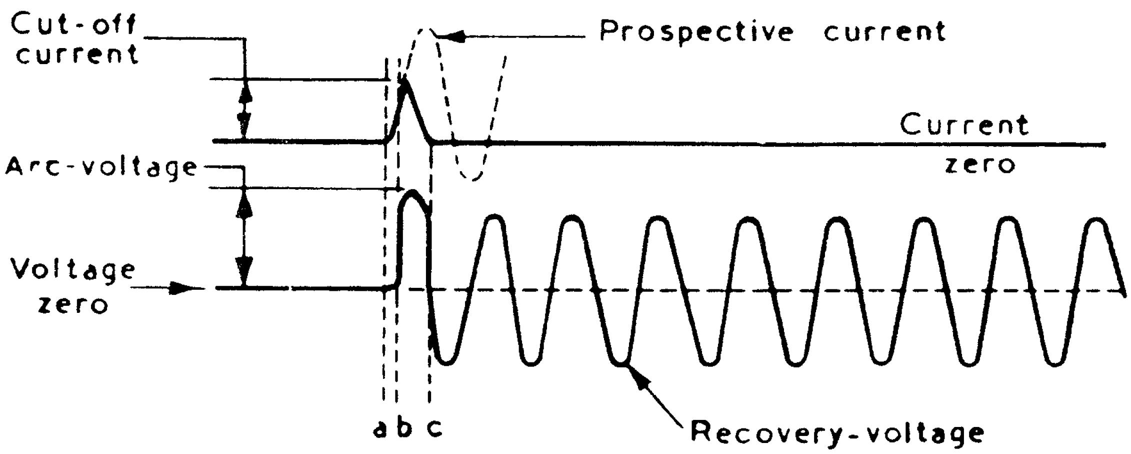
NOTE 2 As indicated in Figure 1(a) a link is substituted for the fuse in phase B.

Figure 3 — Determination of recovery-voltage



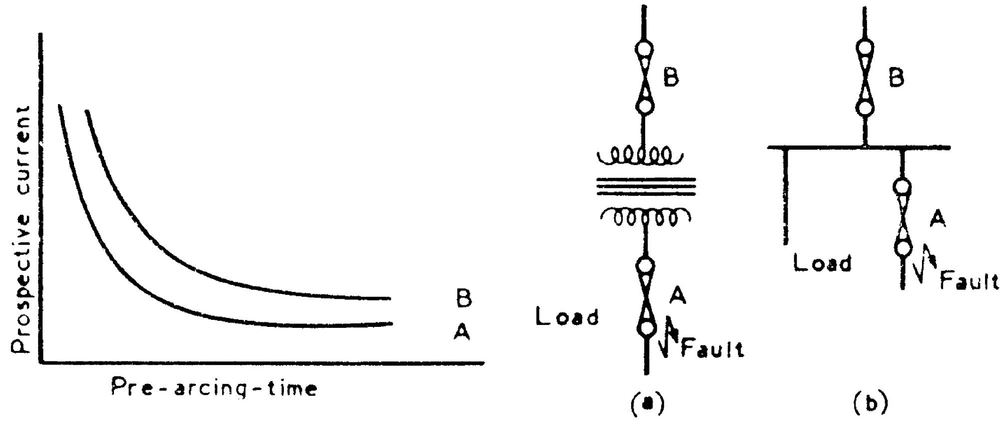
The peak of the prospective current is deemed to be $\frac{GH}{2}$.

Figure 4 — Prospective current oscillogram

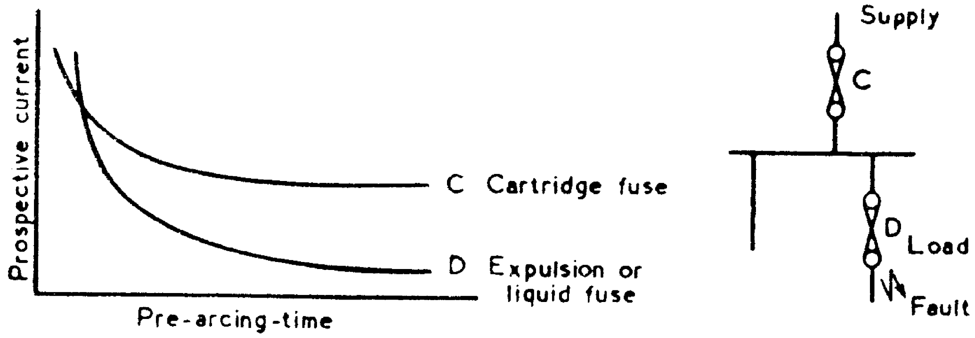


ab = Pre-arcing-time.
bc = Arcing-time.

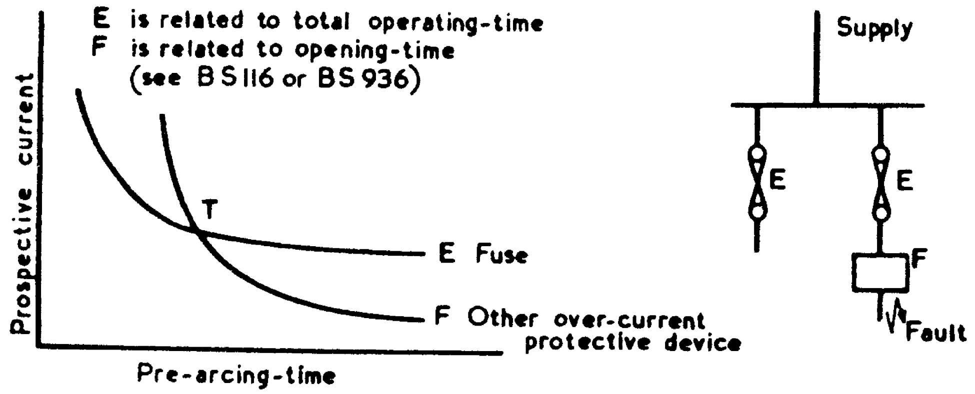
Figure 5 — Oscillogram for large prospective current



(*a*) Typical time/current characteristics of cartridge-fuses of different current-ratings.

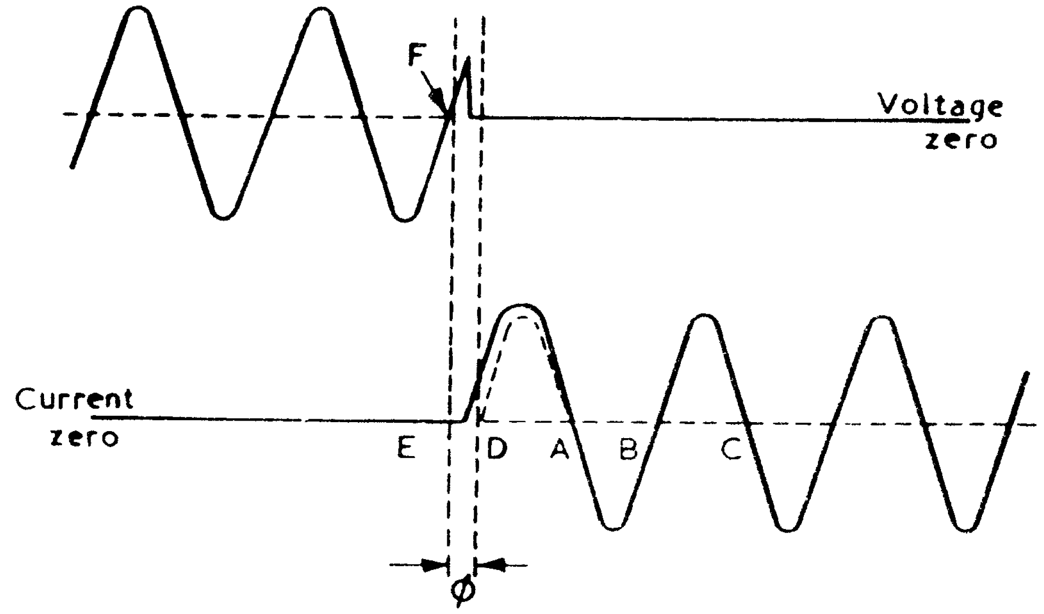


(*b*) Typical time/current characteristics of cartridge-fuse and expulsion-fuse or liquid-fuse.



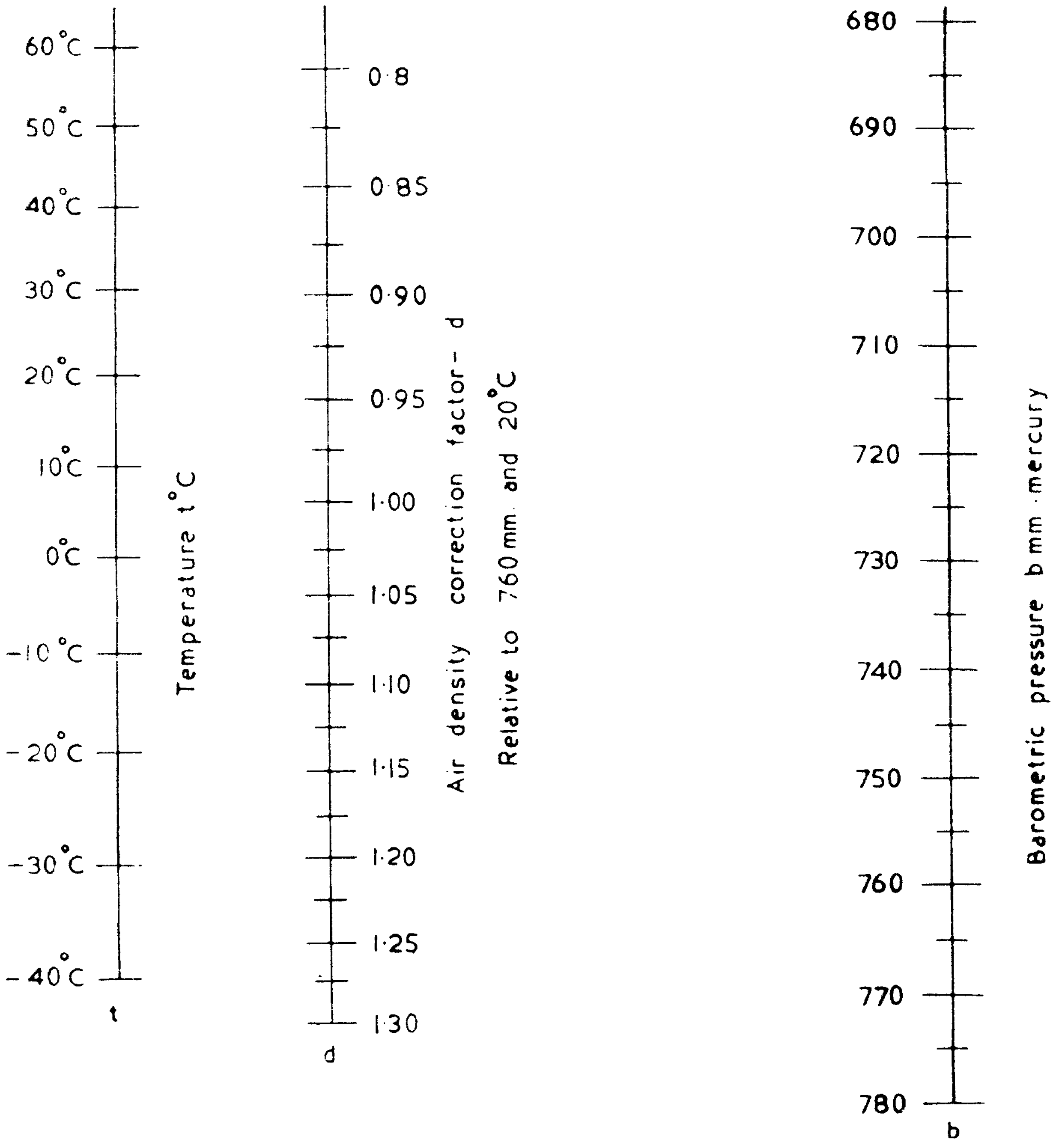
(*c*) Typical time/current characteristics of cartridge-fuse and other over-current device.

Figure 6 — Examples of discrimination



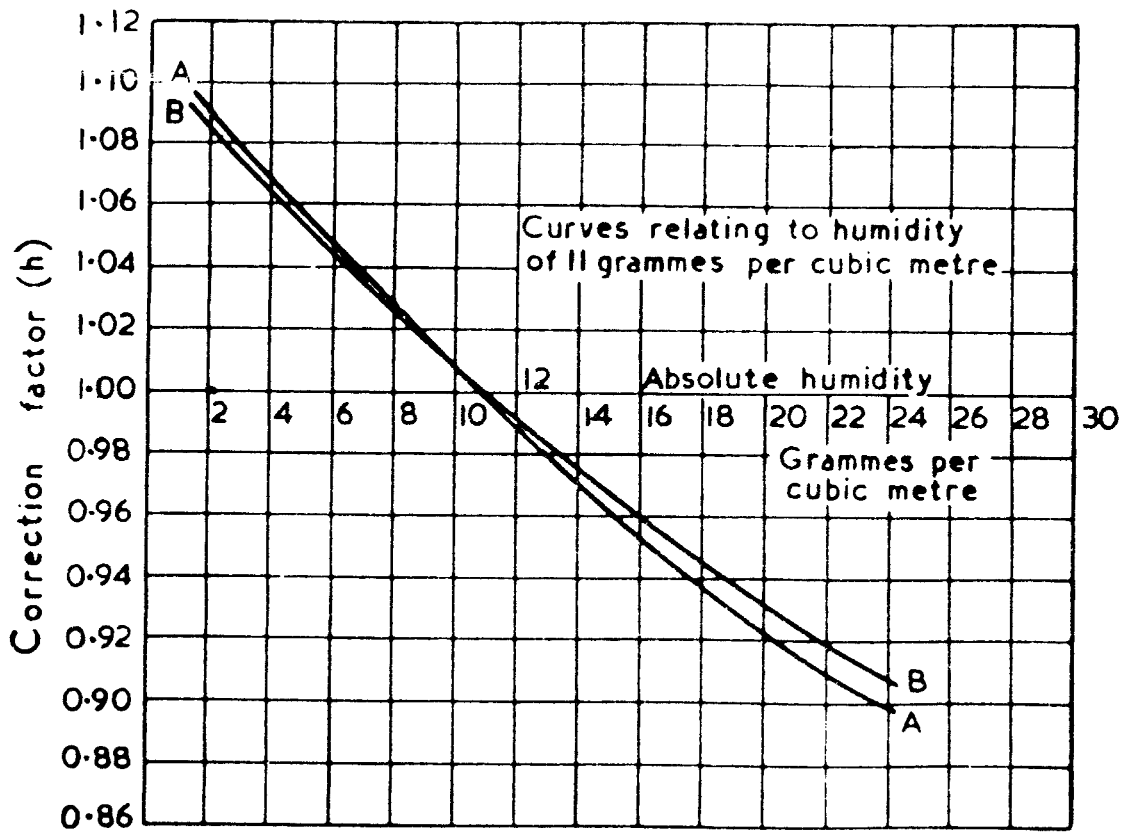
Power factor is cos ϕ.

Figure 7 — Oscillogram for computation of power factor



A straight line drawn through the appropriate values of temperature and pressure passes through the corresponding value of the air density correction factor.

Figure 8 — Air-density correction-factor



Curve ' A ' applies for 1/50 µs positive impulse-voltage tests.
Curve ' B ' applies for 1/50 µs negative impulse-voltage tests.

Figure 9 — Correction-factor for humidity

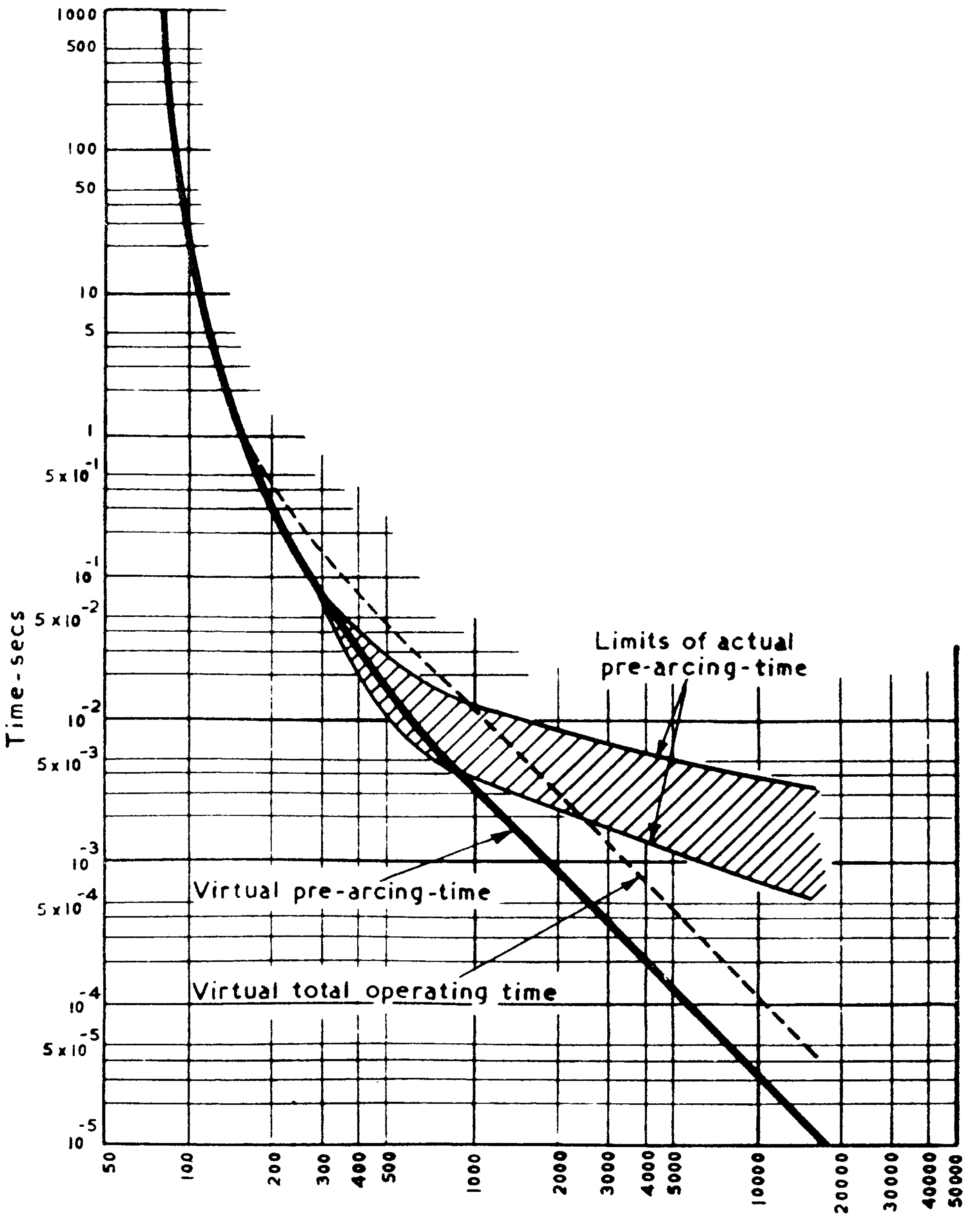


Figure 10 — Virtual time curves

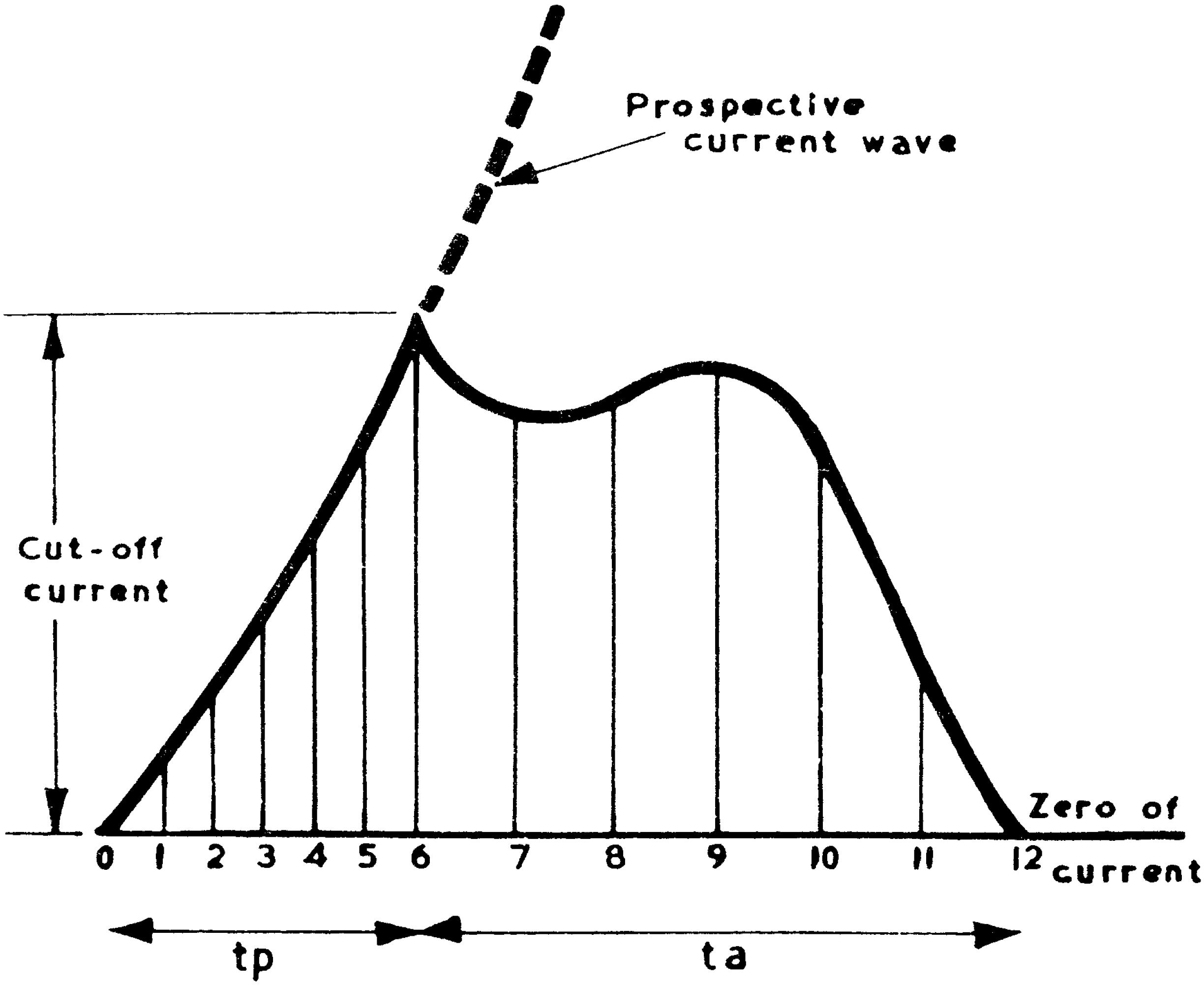


Figure 11 — Determination of virtual time

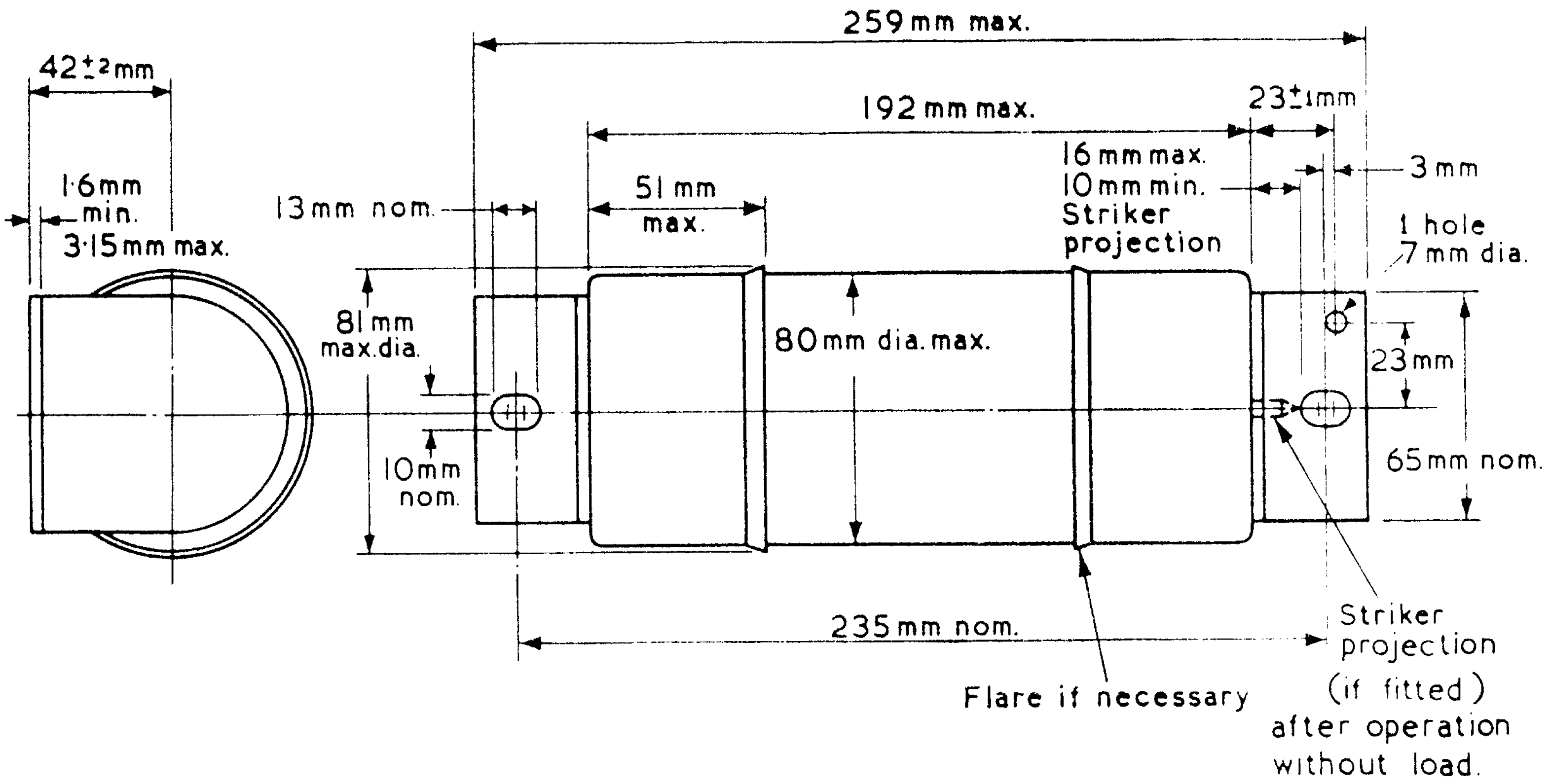


Figure 12 — Dimensions for reference TA1 fuse-links. Voltage 3.3 kV. For use in air

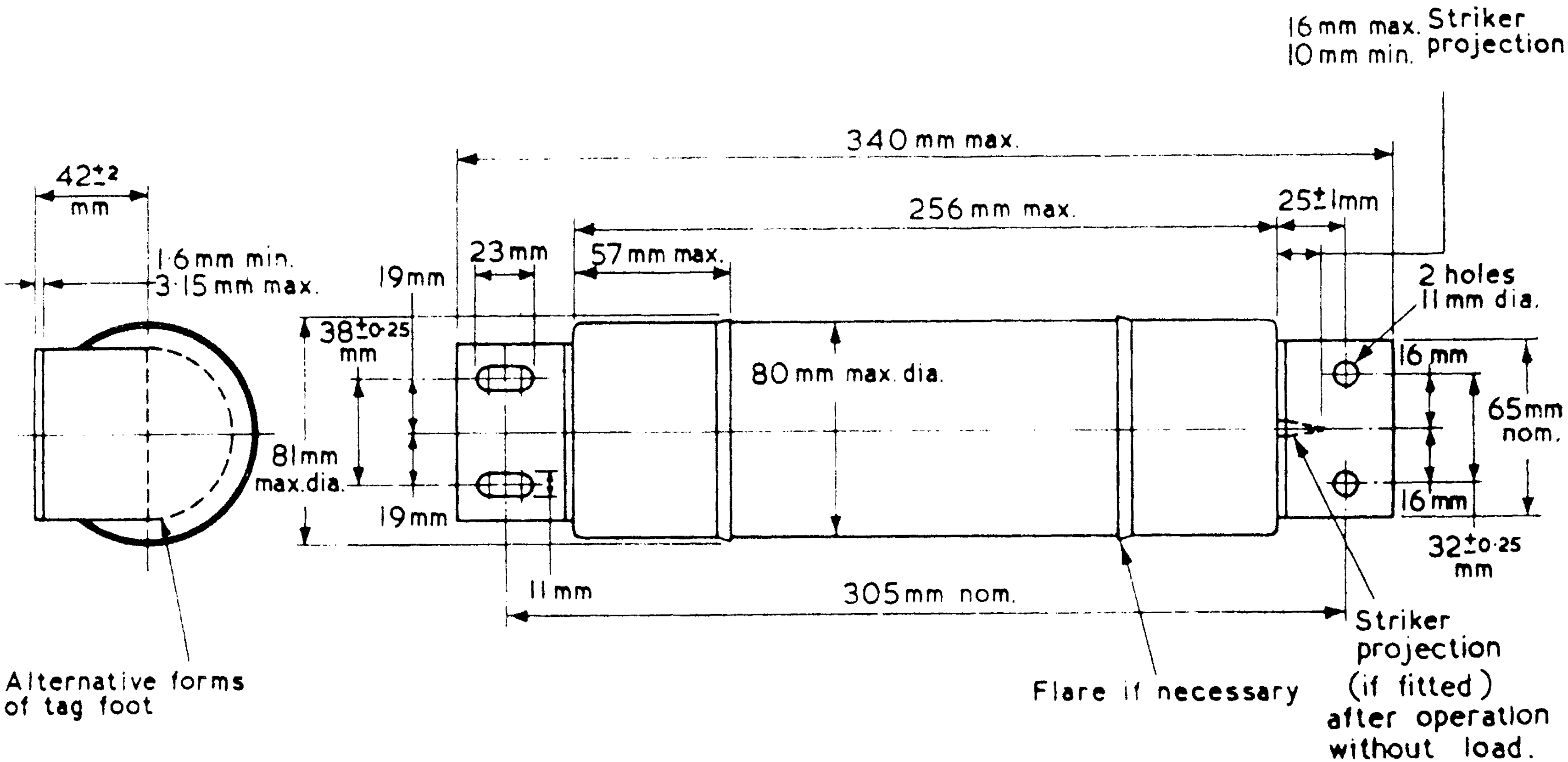
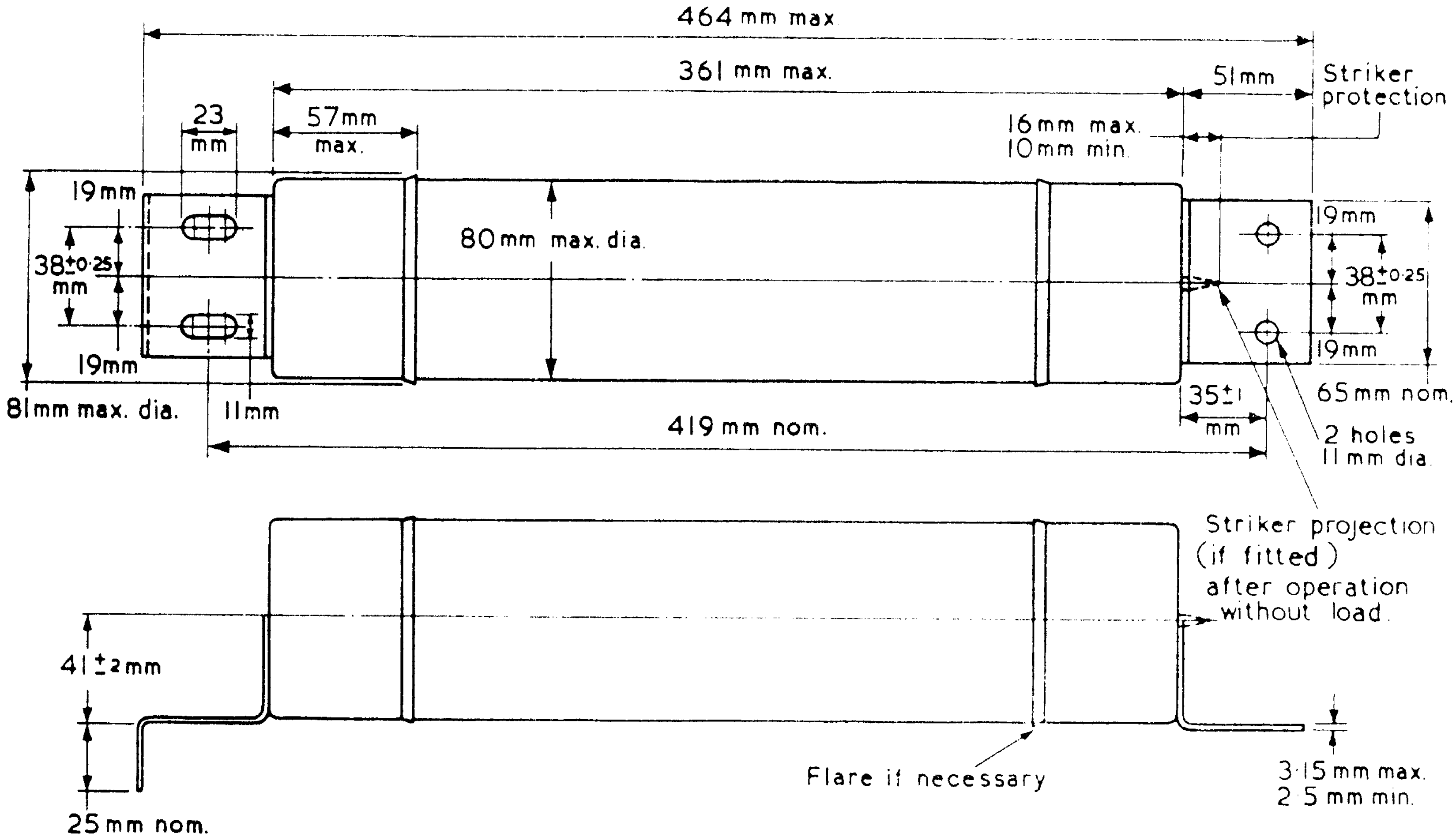
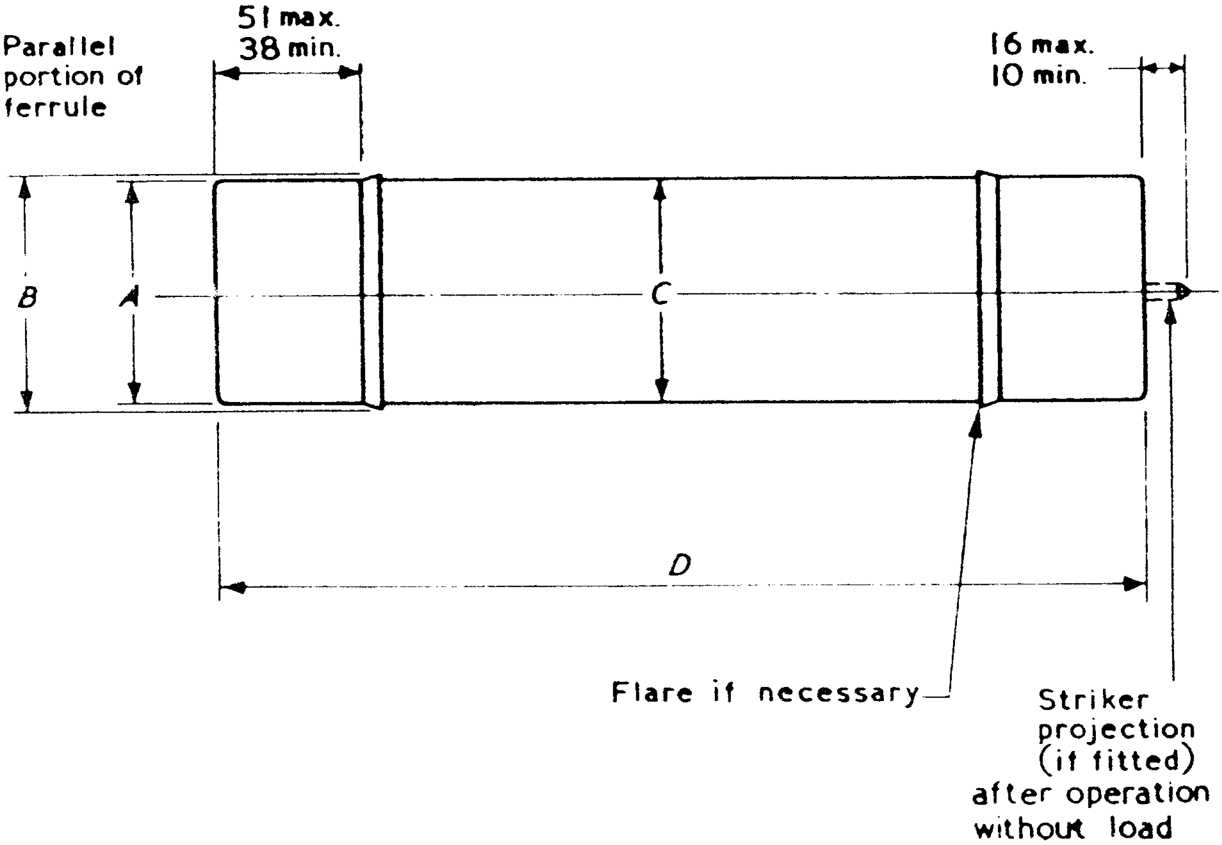


Figure 13 — Dimensions for reference TA2 fuse-links. Voltage 3.3 kV. For use in air



If the extra bend on the fixing tag is inconvenient when connecting in parallel, tags as shown in Figure 12 or Figure 13 may be used on these fuse-links.

Figure 14 — Dimensions for Reference TA3 fuse-links. Voltage 6.6/11 kV. For use in air



(All dimensions are in millimetres)

Reference	Rated voltages[a] kV	Air or oil	A		B	C	D	
			Min.	Max.	Max.	Max.	Min.	Max.
FA 1	6.6, 11	Air	50.3	51.3	55.6	54	357	361
FA 2	6.6, 11	Air	75.7	76.7	81	80	357	361
FA 3	22, 33	Air	50.3	51.3	55.6	54	562	572
FA 4	22, 33	Air	75.7	76.7	81	80	562	572
FA 5	66	Air	75.7	76.7	81	80	911	921
FO 1	3.3, 6.6, 11	Oil	63	64	68	67	252	256
FO 2	3.3, 6.6, 11	Oil	63	64	68	67	357	361

[a] The highest voltage shown against any reference is the maximum rated voltage. See also Subclause **7** b).

Figure 15 — Dimensions of Ferrule-type fuse links for use in air or oil

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