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Specification

Semi-enclosed Electric fuses —

Ratings up to 100 amperes and 240 volts to earth

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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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 23 October 1958

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PD 3614	December 1959	
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Contents

Foreword

Semi-enclosed fuses are used extensively and have given satisfactory service on low- and medium-voltage systems not exceeding 240 volts to earth at points where the breaking-capacity severity is limited. Such fuses are usually associated either with switches in composite units, or with distribution boards, used on two- or three-pole circuits, the fuses being enclosed within a single case, which is often of metal and is then connected to earth.

The semi-enclosed fuses covered by this standard are suitable for certain applications only. Where fuses are required for points in a system where the prospective short-circuit current exceeds the test values given in the standard, or higher breaking-capacity ratings are required, the appropriate Parts of BS 88 "*Cartridge fuses for voltages up to and including 1 000 V a.c. and 1 500 V d.c.*", or with BS 1361 "*Cartridge fuses for a.c. circuits in domestic and similar premises*" should be used. BS 88, "*Electric fuses for circuits of voltage-ratings up to 660 volts*", should be used.

Fuses within the scope of this standard are not sensitive to normal electromagnetic disturbances, and therefore no immunity tests are required.

Significant electromagnetic disturbance generated by a fuse is limited to the instant of its operation. Provided that the maximum arc voltages during operation in the type test comply with the requirements of the clause in this standard specifying maximum arc voltage, the requirements for electromagnetic compatibility are deemed to be satisfied.

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 22 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 standard relates to low-voltage and medium-voltage semi-enclosed fuses, having ratings of 240 volts maximum to earth, and 100 amperes or less, intended for any of the a.c. categories of duty at 50 Hz included in Table 1 and for use under service conditions not more onerous than those described in Clause **2**.

2 Service conditions

The service conditions for which fuses complying with this standard are suitable are as follows:[1)]

a) *Voltage*. Circuits in which the voltage between lines does not exceed the rated voltage of the fuse, and in which the voltage to earth does not exceed 240 volts.

b) *Current*. Carrying currents from zero current to rated current and breaking currents from the minimum fusing current to the breaking-capacity rating at power factors not more severe than those corresponding to the relevant category of duty.

c) *Ambient temperature*. The temperature of the air surrounding the fuse is assumed to have a peak value not exceeding 40 °C, with an average value not exceeding 35 °C over twenty-four-hour periods.

NOTE Under normal conditions of service, the available cooling air is subjected to natural atmospheric variations of temperature, and the peak temperature occurs only occasionally during the hot season; on those days when it does occur it does not continue for long periods. Meteorological records indicate that temperatures at least 10 degC below the peak temperature will occur within the twenty-four-hour period, and that the average temperature over any twenty-four-hour period that includes the peak temperature will be at least 5 degC below the peak value.

d) *Altitude*. An altitude not exceeding 2 000 metres.

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

f) *Enclosure*. Enclosures similar to those specified for the tests in Section 3.

NOTE Where the fuses are mounted in an enclosure it should be established that the clearances between fuses and between each fuse and the wall of the enclosure are not less than those used for the test.

3 Definitions[2)]

For the purposes of this British Standard the following definitions 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 comprises all the parts that form the complete device

3.2
semi-enclosed fuse

a fuse in which the fuse element is neither in free air (other than the air in any external containing case not forming part of the fuse) nor totally enclosed

3.3
fuse element

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

NOTE Semi-enclosed fuses have easily renewable fuse elements, usually of wire. It is normally left to the user to fit the elements according to the desired current rating.

3.4
fuse contact

a contact suitable for engaging with a fixed contact, and capable of having a fuse element attached to it

3.5
fuse carrier

a removable holder, fitted with fuse contacts, for carrying a fuse element

NOTE A container for a fuse element may form a fuse carrier or part of a fuse carrier.

3.6
fixed contact

a contact, connected to a fixed terminal, suitable for engaging with a fuse contact

3.7
fuse base

that part of a fuse which carries the fixed contacts

3.8
minimum fusing current

the minimum current at which a fuse element in a fuse will melt

3.9
current rating

a current, less than the minimum fusing current, stated by the manufacturer to be the current that the fuse will carry continuously without deterioration

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1) Where service conditions differ appreciably from those specified, the manufacturer should be consulted in selecting fuses with appropriate ratings.

2) See also further notes on terminology, given in Appendix A.

3.10
size

the maximum current rating (expressed in amperes) that a fuse may have when fitted with the appropriate fuse element

NOTE A fuse of one size (say 100-ampere) may be fitted with a fuse element to give it some smaller current rating (say 80-ampere). This matter is within the control of the user. Fuse contacts, fuse carriers, fixed contacts and fuse bases are usually described by stating the size of the fuse of which they are a part.

3.11
fusing factor

the ratio, greater than unity, of the minimum fusing current to the current rating of a fuse, namely:

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Current rating}}$$

(see Appendix **A.2**)

3.12
prospective current

the current (the r.m.s. value of the alternating component of an alternating current) that would flow, under any conditions, including test or fault conditions, on the making of the circuit when the circuit is equipped for the insertion of a fuse but the fuse is replaced by a link of negligible impedance. (See Appendix **A.3**)

3.13
loop

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

NOTE 1 For the purpose of indicating the number of current zeros during arcing time, arcing time may be referred to as including a stated number of loops.

NOTE 2 As shown in Figure 9 and Figure 10, successive loops may have different durations and amplitudes in the region of initiation of current. The larger loops are called major loops and the smaller loops are called minor loops.

3.14
cut-off

if the melting of a fuse element prevents the current through the fuse reaching the otherwise attainable maximum (the peak current of the first major loop in an a.c. circuit), 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 **3.12**).

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

3.15
breaking-capacity rating

a prospective current stated by the manufacturer to be the greatest prospective current to which a fuse may be subjected under prescribed conditions of voltage and of power factor

3.16
voltage rating

a voltage stated by the manufacturer to be the highest declared voltage, and the highest voltage to earth, if less than 240 volts, that may be associated with the fuse

3.17
arc voltage

the voltage across a fuse during the arcing time

NOTE 1 The maximum value of the arc voltage may exceed the peak value of the a.c. recovery voltage.

NOTE 2 See Appendix **A.6**.

3.18
pre-arcing time

the time between the commencement of a current large enough to cause a break in a fuse element and the instant when the break is initiated

3.19
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

3.20
total operating time

the sum of the pre-arcing time and the arcing time

3.21
recovery voltage

of a circuit opened by a fuse or fuses. The r.m.s. value of the normal-frequency a.c. voltage across the terminals of the fuse or fuses after the opening of the circuit

3.22
operation

the process in a fuse between the beginning of the pre-arcing time and the end of the arcing time. Operation is sometimes called blowing

3.23
discrimination

in a series circuit containing two or more current-interrupting devices: the operation, under over-current or short-circuit conditions, of only the current-interrupting device appropriate to the portion of the circuit affected. (See Appendix **F.6**)

3.24
duty

the satisfactory opening of a fuse, at voltages not higher than the voltage rating of the fuse, of the circuit or circuits protected by it under conditions that produce for the requisite length of time any prospective current greater than its minimum fusing current up to its breaking-capacity rating

Section 2. Requirements

4 Voltage ratings

The preferred a.c. rated voltages are 240 V single-phase and 415 V three-phase.

5 Sizes

The sizes of fuse for each category of duty (see Clause **9**) shall be as stated in Table 1.

Table 1 — Sizes for each category of duty

Category of duty	Number of sizes	Standard sizes (Maximum current rating in amperes)
S1A	6	5, 15, 20 30, 45, 60
S2A	7	5, 15, 20, 30, 45, 60, 100
S4A	4	30, 45, 60, 100

6 Temperature rise at rated current

All parts of fuses shall be so designed and proportioned that when they are carrying their rated current continuously, in accordance with Clause **17**, the temperature rise of the fuse contacts and of the fixed terminals[3)] at the top of fuses mounted vertically, or at either end of fuses mounted horizontally, does not exceed 55 deg C.

7 Fusing factors

Fusing factors, which shall not exceed 2.0, shall be declared by the manufacturer. They shall be ascertained by calculating the ratio of the minimum fusing current, determined according to Clause **19**, to the current rating.

8 Time/current characteristics

Time/current characteristics shall be prepared in accordance with Clause **18** and the manufacturer shall make copies available to the purchaser upon request.

The curves shall be prepared with both axes scaled logarithmically, and shall show prospective currents up to the breaking-capacity rating, plotted against pre-arcing times.

The curves shall be supplemented with information regarding arcing times and, if the manufacturer thinks it necessary, with data on the relationship between cut-off currents and prospective currents.

9 Performance

Fuses shall open circuits adjusted for any prospective current greater than their minimum fusing currents, up to their breaking-capacity ratings, and shall be tested for duty in accordance with Clauses **20** to **23**.

One or more of the categories of duty given in the first column of Table 3 shall be assigned to each fuse.

NOTE The categories of duty arc distinguished by the values of prospective current of the test circuit and are denoted by numerals prefixed by the letter "S" (indicating that the fuse is semi-enclosed).

The category of duty to which any fuse is assigned shall be one having a distinguishing value of prospective current not greater than the breaking-capacity rating of the fuse.

For example:

A fuse having a breaking-capacity rating greater than 2 000 amperes, but less than 4 000 amperes, is, for example, placed in category of duty S2A.

A fuse having a breaking-capacity rating less than 1 000 amperes is outside the scope of this standard.

The power-factor of the a.c. test circuits shall be of the appropriate values as stated in Table 3.

Reports of type tests of performance shall include the details given by Appendix G.

10 Contacts

Fuse contacts and fixed contacts shall be so constructed and of such materials that, when the fuse is properly installed and service conditions are not more severe than those given in Clause **2**, adequate contact is maintained between the fuse contacts and the fixed contacts, even after repeated engagement and disengagement.

11 Spacing of fixed contacts

Fixed contacts and their terminals shall be so spaced and shielded that an arc cannot be maintained when the fuses are tested in accordance with Clauses **20** to **23**.

12 Terminals

Terminals shall be so designed that they effectively contain all conductor strands of cables for which they are intended.

[3)] Or cable sockets, when used.

Table 3 — Categories of duty for fuses suitable for a.c. circuits

1	2	3	4	5
Category of duty	**Breaking-capacity rating**	**Test**	**Prospective current of test circuit**	**Power factor of test circuit (lagging)**
	Amperes			
S1A	1 000	(i)	1 000 amp	0.8–0.9
		(ii)	5–7 times minimum fusing current	0.4–0.5
S2A	2 000	(i)	2 000 amp	0.7–0.8
		(ii)	5–7 times minimum fusing current	0.4–0.5
S4A	4 000	(i)	4 000 amp	0.7–0.8
		(ii)	5–7 times minimum fusing current	0.4–0.5

13 Non-metallic parts

All non-metallic parts of fuses shall be constructed of insulating material. The material shall be non-hygroscopic except that tubular linings or the like, enclosing fuse elements, need not be non-hygroscopic. Material liable to track shall not be used unless the design is such as to provide permanent protection from tracking.

The material shall be non-ignitable under the specified service conditions as proved by compliance with the specified tests.

14 Shielding and prevention of danger

Fuse elements shall be so guarded or positioned that, when tested in accordance with Clauses **20** to **23**, danger from overheating and arcing is prevented and scattering of hot metal or other substances does not occur.

Fuses shall include suitable fuse carriers, and fuse elements, fuse contacts and fixed contacts shall be so shielded as to protect persons from inadvertent contact with live metal when a fuse carrier is being withdrawn. Fuse carriers shall be of such form and material as to protect persons from shock or burns.

Section 3. Type tests

15 General

All tests are type tests and shall be made by the manufacturer (or by a recognized authority on his behalf) who shall hold available certificates of the tests as evidence of compliance with the requirements of this standard.

The fuses to be used for the type tests shall be identical with those to be used in service in all details likely to affect performance. A test of a fuse of any given size will not necessarily be deemed to prove similar fuses when fitted with fuse elements giving a lower current rating.

The manufacturer shall also hold available detail drawings of the fuses tested and, if required by the purchaser, certify that the fuses are identical in material and performance with those covered by the test certificate.

If alternative positions of mounting are admissible in service, the fuses shall be mounted vertically for the test.

The frequency of the test supply shall be between 45 Hz and 62 Hz.

At the beginning of the test the fuse and the connecting cables shall be approximately at the ambient temperature.

16 Insulation resistance

Fuses with all parts in position except the fuse element shall be tested for insulation resistance when in clean new condition. The test shall be made at a voltage of not less than 500 volts d.c., generated in the measuring instrument or obtained from an independent source.

Fuses shall be mounted in the metal case used for the test specified in Clause **20**, or shall be mounted on a metal plate by the intended fixing means.

The measurement shall be taken after a sufficient time has elapsed for the reading of the indicator to become steady, and shall be made:

a) between the fixed terminals,[4)]

b) between the containing metal case, if any, and the fixed terminals,[4)]

c) between the poles of multi-pole units.

The insulation resistance shall not be less than 50 megohms.

17 Temperature rise at rated current

Fuses shall be tested for temperature rise at rated current in surroundings free from external draughts and in a containing case representative of that which may be used in service.

The temperature rises of the fuse contacts and fixed terminals[4)] at the top of fuses mounted vertically, or at either end of fuses mounted horizontally, and of the connections, shall be measured by thermocouples attached by a low-melting-point alloy or by some equally effective means of attachment.

The points at which the temperature rises are measured shall be:

a) For fuse contacts the point at which, from the design, the maximum temperature rise may be expected to occur.

b) For fixed terminals,[4)] the accessible point closest to the external connection.

The cables connected to fuses on test shall be polyvinyl-chloride insulated (P.V.C.) as in Table 4. A minimum length of 1 m of cable shall be used.

Table 4 — Cables for test connections to fuses

Size of fuse	Size of cable
Amperes	mm^2
5	1
15	2.5
20	2.5
30	6.0
45	10.0
60	16.0
100	35.0

After the fuses have carried their rated currents continuously for sufficient time to allow their temperatures to become steady, the temperature rises shall be not greater than those permitted in Clause **6**.

No correction shall be made to test results where the ambient temperature during the test differs from that stated in Sub-clause **2** c).

NOTE 1 Satisfactory working of fuses tested in containing cases under the conditions specified in Clause **17** ensures satisfactory working of the fuses without their containing cases, but not necessarily in cases different from those used in the tests.

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

18 Time/current characteristics

Time/current characteristics of fuses shall be ascertained by causing them to operate at not less than six different currents so chosen as to facilitate the production of a curve of the kind shown in Figure 13.

One of the currents, usually the least, shall be not greater than 1.05 times the minimum fusing current of the fuse, and another of the currents, usually the greatest, shall be great enough to cause the fuse to operate in not more than 0.5 second.

Fuses shall be tested in surroundings free from draughts and in a containing case representative of that which may be used in service.

Pre-arcing times shall be plotted and the time/current characteristic shall be deemed to be a curve drawn as indicated by all the plotted points. Points corresponding to pre-arcing times at higher currents obtained from the tests specified in Clause **22** shall be plotted on the same graph, and the curve shall be extended in accordance with the indications of these points.

19 Minimum fusing current

Fuses shall be tested for minimum fusing current in surroundings free from draughts and in a containing case representative of that which may be used in service.

For each fuse, two currents shall be determined, one of which is 90 per cent of the other; at the larger the fuse element shall melt within the appropriate time indicated in Table 5, and at the smaller the fuse element shall not melt within that time. The minimum fusing-current shall be deemed to be the arithmetical mean of the two currents so determined.

For the purpose of this test, two completely identical fuses or sets of fuses shall be provided, one for use in ascertaining the larger current, and one for use in ascertaining the smaller current.

The appropriate duration of a test for minimum fusing current depends on the size of the fuse (see Clause **5**), and shall be as stated in Table 5.

[4)] Or cable sockets, when used.

Table 5 — Duration of test for minimum fusing current

Size of fuse	Appropriate duration of test
Amperes	Hours
5	0.75
15	1.00
20	1.00
30	1.25
45	1.50
60	1.5
100	2.0

20 Preparation of fuses for tests for duty

Fuses shall be fitted with fuse elements appropriate to their current rating.

Fuses shall be tested in bare metal cases and mounted on any insulation pad that may be specified by the manufacturer.

All parts of the metal case shall be effectively electrically bonded and collectively connected to earth and to the appropriate point of the source of energy through a fine wire fuse, wired with copper wire not greater than 0.1 mm diameter with a fusible length of not less than 75 mm.

Fuses of 240-volt single-phase a.c. rating shall be tested singly. Fuses of 415-volt three-phase a.c. rating shall be tested as a set of three fuses.

21 Test circuit and earthing arrangements

The terminal at which, it appears from inspection that arcing to the case is the more likely to occur shall be connected to the pole of the test supply that is unearthed. The arrangement of the circuit shall be that given in one of the Figure 1 to Figure 4, according to the voltage rating of the fuse.

The source of energy for the tests shall be capable of giving the required prospective currents (measured as shown in Appendix B) and shall produce a recovery voltage (measured at points shown in Appendix E) equal to the voltage rating of the fuse (see Clause **4**) with a tolerance of plus 15 per cent and minus 0. If necessary the voltage of the test circuit may be increased initially above the maximum value in order to ensure that the recovery voltage will have the required value.

The recovery voltage shall be maintained at the test voltage, with a tolerance of plus 15 per cent and minus 0 per cent, for not less than 30 seconds immediately after the opening of the circuit by the fuse in order to demonstrate that the fuse will withstand indefinitely continued application of the test voltage.

The power factor of a polyphase circuit shall be deemed to be the average of the cosines of the angles of lag in all phases. The power factor of any phase shall not vary from the average by more than 25 per cent of the average. The power factor shall be computed by the method shown in Appendix C.

For a.c. circuits, the power factor shall be in accordance with the values specified in Table 3.

a) *Fuses of* 240-*volt a.c. rating*. The arrangement of the circuit shall be as indicated in Figure 1 or Figure 2.

For Test (i) in Sub-clauses **22** a and **22** b the current shall be switched on at an instant between 0° and 60° on the rising-voltage wave. In the test circuit of Figure 2 this requirement will usually be met on only one of the three fuses and one test application is valid as a test on one fuse only.

Fuses which pass the test specified in Sub-clause **21** b (see Figure 4) are suitable for rating at 240-volt single-phase a.c. without further test.

b) *Fuses of 415-volt three-phase a.c. rating*. The arrangement for tests shall be as indicated in Figure 4, and the neutral point of the supply shall be connected to earth.

22 Tests for duty

Fuses in categories of duty S1, S2 and S4 shall be tested according to Sub-clause a).

With the exception of the fuse elements, the same fuses shall be used throughout the tests given in Sub-clause a) without the renewal of any parts. Each separately-detailed test shall be made three times.

The information to be included in reports of type tests for duty shall be as given in Appendix G.

On three-phase tests it may be found that one fuse remains unblown at the end of the test. Provided that at least two *adjacent* fuses have blown the test can be considered satisfactory, and sufficient tests must be made to achieve this. To obtain these conditions without additional tests, it is permissible to replace one of the outer fuses by a solid link or to increase the size of the fuse wire, but it should be realized that this arrangement appreciably increases the severity of the test on the remaining fuses and may only be used with the agreement of the manufacturer.

a) *Fuses in categories of duty* S1, S2 *and* S4.
Test (i). Each fuse shall be tested in the appropriate testing circuit specified in Clause **21**, and the prospective current shall be not less than 100 per cent and not more than 115 per cent of the breaking-capacity rating of the fuse. The latter tolerance may be exceeded with the consent of the manufacturer. The power factor shall be in accordance with the appropriate value in Table 3, for a given category of duty.

Test (ii). The same test circuit as described for Test (i) above shall be used, but with a prospective current of value five to seven times the minimum fusing current, and the power factor shall be in accordance with the appropriate value in Table 3.

The additional impedance necessary to reduce the current below that of Test (i) shall be arranged in the positions indicated in R_2, and X_2 in the figures.

23 Criteria of failure during tests for duty

Fuses shall be deemed not to comply with Clause **9** if one or more of the following occur:

1) Melting of the fine-wire fuse, indicating arcing to the metal case.

2) Arcing between fuses on tests involving two or more fuses.

3) Ignition of the fuses, or damage of neighbouring apparatus.

4) Damage sufficient to render one or more of the following parts unserviceable without repair: fuse contacts, fuse carriers, fixed contacts, fuse bases, cases or any other parts not intended to become unserviceable on the melting of the fuse element.

5) Reduction of the insulation resistance between terminals of the fuse to less than 100 000 ohms when measured at 500 volts within three minutes from the conclusion of the test.

Section 4. Marking

24 Marking of fuse carriers

Fuse carriers shall be clearly and indelibly marked with the following particulars:

1) Size (see Clause **5**) (e.g. 15 A).

2) Voltage rating (see Clause **4**) (e.g. 240 V).

3) Maker's name or identifying mark (e.g. A, B and C).

4) Categories of duty (see Clause **9**) (e.g. S1A).

5) The number and date of this British Standard (e.g. 3036:1958).

NOTE The marking shown in the above examples in parentheses would indicate a fuse with a maximum current rating of 15 amperes suitable for both 240 volt single-phase a.c. where the prospective short-circuit current does not exceed 1 000 amperes.

Appendix A Notes on terminology

A.1 A fuse and its parts

The term "fuse" as applied to a protective device is by definition to be taken as applying to the device as a whole, and not to any of its individual parts (a fuse element, for example, is often, but wrongly, called a "fuse"). The component parts of a fuse are illustrated in Figure 5.

A.2 Time/current characteristic, minimum fusing current, current rating, and fusing factor

The time/current characteristics of fuses, illustrated typically in Figure 13, are of value in connection with the selection of fuses (see Appendix F). In the determination of time/current characteristics the fuses start approximately from the ambient temperature (i.e. a temperature generally less than 35 °C).

When a fuse that has been carrying a current less than its minimum fusingcurrent for some time blows at some greater current, the pre-arcing time is in general (owing to pre-heating) less than that shown by the time/current characteristic.

At currents smaller than the minimum fusing current a fuse does not give protection, because it does not blow (or blows only after an indeterminately long time). It may, however, deteriorate if it continuously carries currents greater than its rated current.

The term "current rating" applied to a fuse is synonymous with the terms "normal current", "current-carrying capacity", and so on, used for other electrical apparatus. Current rating (which, as Definition **3.9** indicates, is less than minimum fusing current) is assigned by the manufacturer from the results of tests made in accordance with Clause **17**.

Clause **7** has been formulated to cover fuses now on the market, but, except to the extent provided by Clauses **6** and **17**, compliance with this standard is not necessarily complete proof that fuses will carry their rated currents for long periods without deterioration.

Fusing factor forms, a ready means of stating the range of currents, between rated current and minimum fusing current, at which a fuse does not give protection, and within which it may not be used without the possibility of deterioration or of a temperature rise greater than is permitted by Clause **6**.

A.3 Oscillograms, prospective current and cut off

In tests for duty, currents and voltages are usually measured on an oscillograph, or possibly with an ammeter and a voltmeter.

The full-line part of Figure 6 is typical of oscillograms obtained with an a.c. fuse that opens the circuit before the current reaches its first major peak. Were this not the case the current (calculated in the usual way from the known voltage, resistance, and reactance of the circuit, but neglecting the resistance of the fuse) would have been as shown by the dotted line marked "prospective current". The fact that the calculated value is not obtained is due to the cut-off effect of the fuse.

Because of this kind of operation it has become necessary to introduce the terms "cut off" and "prospective current" as defined in Clause **3**, Definitions **3.12** and **3.14**. Although it is true that the impedance of a fuse may reduce the greatest possible current in a circuit to a value somewhat less than that of the greatest prospective current of the circuit, the limitation of current from this cause is not what is understood by cut off; cut off is produced by the inherent mode of action of the fuse, which causes the fuse element to melt before the prospective current can be fully developed.

Prospective current may have any value according to circuit conditions. It 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 greatest.

Some fuses would cut off only at currents greater than their breaking-capacity rating, and no fuse cuts off at all prospective currents. This means that the current oscillogram of all fuses is, at some prospective currents, of the general type shown in Figure 9 for a.c. fuses.

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 nearly 2 I, where I is the peak-current corresponding to the (r.m.s.) prospective current. To avoid possible complication of statement, therefore, Definition **3.12** has been adopted, though it often enough allows the numerical value of the cut-off current to be greater than the numerical value of the corresponding prospective current (see Note 1 to Definition **3.14**).

A.4 Pre-arcing time, arcing time and total operating time

The pre-arcing time, the arcing time, and the total operating time, alter with prospective current, in general as indicated by Figure 7 and Figure 9 for a.c. The arcing time usually becomes a greater proportion of the total operating time as the prospective current increases. This fact is important in connection with discrimination (see Appendix **F.6**).

A.5 Power-factor

The power-factor of an alternating-current circuit is theoretically $R/\sqrt{(X^2+R^2)}$, where X (= $2\pi fL$) is the reactance of the circuit (in ohms), L is the inductance of the circuit (in henries), and R is the resistance of the circuit (in ohms); when X and R are constant it is the ratio of watts in the circuit to corresponding volt-amperes, and, further, when the shape of the current-wave is sinusoidal it is expressible as the cosine of the electrical angle ϕ between the supply voltage and the current.

The values of power factor given in this specification are those assigned to a testing circuit. They represent values that may be obtained in service, but they should not be confused with the power factor of a circuit when it is carrying normal current.

A.6 Arc voltage and recovery voltage

The voltage drop across a fuse during most of its pre-arcing time is relatively small, and in oscillograms taken during normal type tests it appears to be approximately a continuation of the zero voltage trace. It is shown as the voltage appearing across the fuse between times a and b in Figure 7 and Figure 9.

When arcing starts there is an immediate increase of voltage across the fuse, and the amount of the increase depends on the type of fuse and on the prospective current. With large prospective currents, the arc voltage may quickly reach a relatively high value, as shown in Figure 7, and it then decreases to the initial recovery voltage, as shown between b and c in Figure 7. With smaller prospective currents the initial are voltage is smaller, and if it is less than the recovery voltage it increases to the higher value represented by the initial recovery voltage as shown between b and c in Figure 9.

A.7 Operation and duty

Operation (or blowing) 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 (or blowing) as defined, but "melting" (or "fusing") can only be properly used to describe what goes on in a fuse during a part of the pre-arcing time. The term "failed" is also used occasionally in connection with "operation" (or "blowing"); the only correct implication then is that the fuse has, for example, shown one or more of the phenomena described in Clause **23**, but in fact the intention often is, wrongly, to imply just the opposite, and the word should therefore be used with care.

A fuse that operates satisfactorily at a given prospective current may not do so at all smaller prospective currents; and therefore, since a fuse is required to operate satisfactorily at all prospective currents greater than its minimum fusing current up to its breaking-capacity rating, the tests specified in Clause **22** have been chosen to ensure as far as is practicable that standard fuses are capable of doing this.

Appendix B Measurement of prospective current and cut-off current

Prospective current is measured in a test (made as a preliminary to a test for duty) 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 waveform it reaches shortly after the circuit is made. The time between the making of the circuit and the reaching of the measured value usually depends only 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 depends on the power-factor of the circuit and 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 depends on the power factor of the circuit.

The current obtained in an a.c. prospective current test may or may not reach a constant-amplitude wave-form. If it does so in a time comparable with the time-constant of the d.c. component of the transient asymmetrical current, the r.m.s. value of the constant-amplitude waveform, measured by an ammeter or otherwise, is the prospective current of the test circuit.

If the required current is large it is usually not possible to obtain a constant-amplitude waveform 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. Under 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 0.02 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 on this oscillogram (see Figure 10):

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

b) The point O, corresponding to the current 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 (i.e. midway between 0 and 0.02 second after the circuit is made).

c) 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 0.02 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 duty, a constant-amplitude waveform is not reached in an a.c. circuit (see Figure 7). It is difficult therefore to refer to cut-off current in terms of an r.m.s. value in an a.c. circuit, and cut-off current is therefore measured as the instantaneous value of the maximum current reached when a fuse cuts off.

Because cut-off current is measured in instantaneous amperes, and prospective current in r.m.s. amperes, in an a.c. circuit, the numerical value of the cut-off current may be greater than the numerical value of the corresponding prospective current (see Note 1 to Definition **3.14**).

Appendix C Computation of power factor and time constant from oscillograms

C.1 Power factor

The power factor of an alternating-current circuit is computed from oscillograms in accordance with the following methods:

METHOD 1. If the asymmetry of the prospective current is sufficient, the angle ϕ (see Appendix **A.5**) may be determined from, the curve of the d.c. component of the prospective current wave as follows:

a) Determine the time-constant T of the d.c. component, which has the general form:

$$i_d = I_{do}\, e^{-\frac{t}{T}}$$

where

- i_d is the value of the d.c. component at any instant,
- I_{do} is the initial value of the d.c. component,
- T is the time constant in seconds of the test circuit,
- t is the time interval in seconds between i_d and I_{do},
- and e is the base of Napierian logarithms.

This can readily be done as follows:

i) Measure the value of I_{do} (i.e. the initial value), and the value of i_d at any other time t.

ii) Determine the value $e^{-\frac{t}{T}}$ by dividing i_d by I_{do}.

iii) From a table of e^{-x} determine the value of $-x$ corresponding to the ratio i_d/I_{do}. (The value of e^{-x} can be obtained readily from a table of Napierian logarithms by taking the reciprocal of the number of which x is the logarithm.)

iv) The value x represents t/T, and so T can be determined by dividing t by x.

b) Determine the angle ϕ from $\phi = \arctan \omega T$, where ω is the actual frequency multiplied by 2π. The power-factor is then $\cos \phi$.

METHOD 2. For the higher values of power factor the asymmetry is likely to be insufficient for an accurate determination of *T*, and this alternative method should then be used; it requires a voltage trace in addition to a prospective current trace, as shown in Figure 11. 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 stepped back along the current-zero, making AD equal to AB; it may be necessary to do this more than once. A projection E on the current zero is then made from the point F, which represents the last voltage zero before the initiation of the current.

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

Appendix D

Deleted

Appendix E Measurement of recovery voltage

The recovery voltage is measured as follows:

For tests on single fuses in accordance with Figure 1 and Figure 2 the recovery voltage is measured directly across the fuses and the measured value is the recovery voltage for the test.

For three-phase tests in accordance with Figure 4 the recovery voltage is the average of the recovery voltages measured across each of the blown fuses (V_{RC}). If three fuses blow, the average is multiplied by the factor 1.73.

Appendix F Selection of semi-enclosed fuses

General. The most important technical factors upon which the correct selection of fuses for any installation depends are set out below. The headings indicate the kind of information usually desired with enquiries and orders.

1) *System.* A fuse should be used in each conductor of a distribution system, except a neutral conductor, and except a conductor always earthed while the system is alive.

The voltage rating of a set of fuses in a circuit (which may consist of only some of the conductors of a system) should not be less than the voltage (r.m.s. a.c.) between conductors of that circuit, and the voltage between any conductor and earth must not exceed 240 volts.

A fuse proved suitable for a.c. 50 Hz circuits may not be suitable for a.c. circuits at frequencies outside the range specified or for d.c. circuits.

2) *Service conditions.* It should be verified that the service conditions are not more onerous than those given in Section 1.

3) *Breaking capacity.* The duty of a set of fuses under fault conditions should be determined by calculating the fault current, and power factor at the place where the fuses are to be located in the supply system or network, in accordance with some recognized method.

In many a.c. installations of semi-enclosed fuses elaborate calculations are unnecessary, for the following reasons:

a) The resistance and reactance characteristics of small transformers do not vary appreciably between different makes and designs. It is therefore possible to use common values from which the short-circuit current and power factor can be calculated, assuming that the high-voltage network from which the transformer is fed exercises no appreciable influence. (This assumption errs on the safe side since any appreciable effect of the h.v. network would be to reduce the l.v. short-circuit current.)

b) The connections between the supply transformer and the fuses may have a considerable effect upon the values of the short-circuit current and power factor. For low-voltage cables the resistance value is the most important factor, as the reactance is relatively small, and, by neglecting the latter, the necessary measurements or calculations can be considerably simplified without danger to the fuse performance.

c) On the above assumptions, therefore, calculations have been made to establish the total cable resistance required to reduce the short-circuit current, or in some cases to increase the power-factor to that corresponding to the standard categories of duty given in Table 3, assuming a 415-volt three-phase supply. In addition, this resistance has been converted to the equivalent lengths of cables of the same current ratings as the current ratings of semi-enclosed fuses. The results of these calculations are given in Table 6.

Table 6 — Equivalent resistance of lengths of cables of different sizes

Transformer	Minimum added resistance per phase	Power factor	Minimum length of single-core cable per phase in metres					
kVA	Ohms							
Category of duty S1A (1 kA 0.9 PF)			1.0 mm^2	1.5 mm^2	2.5 mm^2	4 mm^2	6 mm^2	
50	0.208[a]	0.9	12	18	29	47	70	
100	0.198	0.94	12	17	28	45	67	
250	0.236	0.99	14	20	33	53	80	
500	0.244	0.995	14	21	34	55	83	
750	0.247	1.0	14	21	35	56	84	
1 000	0.248	1.0	14	21	35	56	84	
Category of duty S2A (2 kA 0.8 PF)			1.5 mm^2	2.5 mm^2	4 mm^2	6 mm^2	16 mm^2	25 mm^2
250	0.109	0.96	10	16	25	37	98	153
500	0.118	0.99	10	17	27	40	106	166
750	0.121	0.995	11	17	27	41	108	170
1 000	0.122	0.996	11	17	28	41	109	172
Category of duty S4A (4 kA 0.8 PF)			4 mm^2	6 mm^2	16 mm^2	25 mm^2	35 mm^2	50 mm^2
250	0.053	0.84	12	18	48	75	104	134
500	0.060	0.96	14	21	54	85	117	159
750	0.061	0.98	14	21	55	86	119	161
1 000	0.062	0.99	14	21	56	87	121	164

[a] In order to raise the power factor to the specified value, the added resistance is in excess of that required for the reduction of the short-circuit current to the current of the particular category of duty.

F.4 Apparatus to be protected

Apparatus to be protected may be put into two general classes:

i) Apparatus the load of which does not fluctuate much above its normal value, e.g. heating circuits. Circuits feeding such apparatus may be called steady-load circuits.

ii) Apparatus the load of which may fluctuate in peaks of comparatively short duration above its normal value, e.g. motor circuits, capacitor circuits, transformer circuits, and lighting circuits, all of which take a transient overcurrent when they are switched into the circuit. Circuits feeding such apparatus may be called fluctuating-load circuits.

a) *Fuses for steady-load circuits.* If, as often happens, fuses are the only protection in a steady-load circuit, their current rating should be at least equal to that of the apparatus. If other over-current protection is provided, or if discrimination requires it, a fuse of greater current rating may be permissible or necessary.

b) *Fuses for fluctuating-load circuits.* For fluctuating-load circuits the fuses should have time/current characteristics such as to allow the transient overcurrent to be carried without blowing. For this purpose it may sometimes be necessary to select fuses of a current rating greater than that of the circuit.

For motor circuits it is necessary to obtain particulars of the magnitude and duration of the starting current, and to select fuses of the required current rating by reference to the appropriate time/current characteristics. Alternatively (and this is usually best) the problem should be referred to the manufacturer of the fuses so that advantage may be taken of his experience.

For capacitor circuits, transformer circuits and fluorescent-lighting circuits the fuses should usually have current ratings about 50 per cent greater than the normal current of the apparatus to be protected. This is only a rough general guide, and the recommendation of the manufacturer of the fuses is to be preferred to an inflexible ruling, since much depends on the time/current characteristics of the fuses.

F.5 Over-current protection

The ability of a fuse to provide satisfactory over-current protection depends on its fusing factor (see Clause **7** and Appendix **A.2**).

F.6 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 protection devices, depends. In view of the complexity of predicting discrimination it is recommended that the assistance of the manufacturer should be sought.

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, the time/current characteristic of any fuse A should lie throughout its length below that of any fuse B nearer to the supply point, as shown in Figure 13.

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.

Pre-arcing time is important for discrimination; further, an alteration in the temperature of the fuses gives them time/current characteristics different from the type-test values; and 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 time/current characteristics are based on pre-arcing times, discrimination cannot be predicted from time/current characteristics, 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.

Figure 14 shows the difference in form between the time/current characteristics of semi-enclosed fuses and those of some cartridge fuses, and when there are such differences a wide separation of current-rating is necessary because of the difference between the forms. The characteristics of the fuses selected must 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 device shall cross at the desired value of current. This promotes continuity of supply by allowing the fuses to operate only when necessary 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 15 shows a typical time/current characteristic of a fuse and some other over-current protective device, A being the take-over point. At currents above A 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, and it is therefore desirable that, quite apart from any question of breaking-capacity, the back-up fuses should have a small cut-off current, it is equally desirable that the other device should have an adequate straight-through fault-current rating.

The take-over point should be at a current less than the breaking capacity of the other device, but to avoid unnecessary blowing of the fuses by any current 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 does not usually 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 of the motor starter.

F.7 Other information

The performance of fuses is affected (e.g. their temperature rise is increased and their breaking capacity may be reduced) if they are enclosed in containing cases, and it is therefore necessary that the manufacturer of the fuses should have full particulars of any such enclosure.

Appendix G Information to be included in reports of type tests for breaking-capacity ratings

G.1 General

a) Date of tests.

b) Reference or report number.

c) Test numbers.

d) Oscillograms.

G.2 Fuses tested

a) Manufacturer's identifying number.

b) Manufacturer's description.

c) Manufacturer.

d) Photograph numbers.

e) Drawing numbers.

f) Particulars of fuse element (e.g. material and gauge).

G.3 Circuit for which fuse is declared suitable

a) Rated voltage.

b) Rated current.

c) Rated frequency.

d) Number of phases or wires.

e) Category of duty.

G.4 Test conditions

a) Minimum clearances to earth

i) Above fuse end.

ii) Below fuse end.

iii) To side of fuse.

iv) In front of fuse.

b) Clearance between fuses when more than one fuse is mounted in one case.

c) Material and dimensions of any insulation pad fitted under fuses.

The above Items a) to c) shall be shown on a drawing which should be included in the test report, and be deemed to define minimum requirements for the mounting of fuses.

G.5 Specification

Tests made in accordance with BS 3036:1958, Clauses **19** to **22**.

G.6 Breaking-capacity tests

a) Applied voltage.

b) Number of poles

c) A.C.

d) Frequency.

e) Diagram of test circuits.

f) Particulars of test No. a i) or b i).

i) Prospective current.

ii) Power factor.

iii) Number of fuses tested.

iv) Physical behaviour during test.

v) Physical condition after test.

vi) Lowest resistance after test.

g) Particulars of test No. a ii) or b iii).

i) Prospective current.

ii) Power factor.

iii) Number of fuses tested.

iv) Physical behaviour during test.

v) Physical condition after test.

vi) Lowest resistance after test.

h) Particulars of test No. b ii).

i) Prospective current.

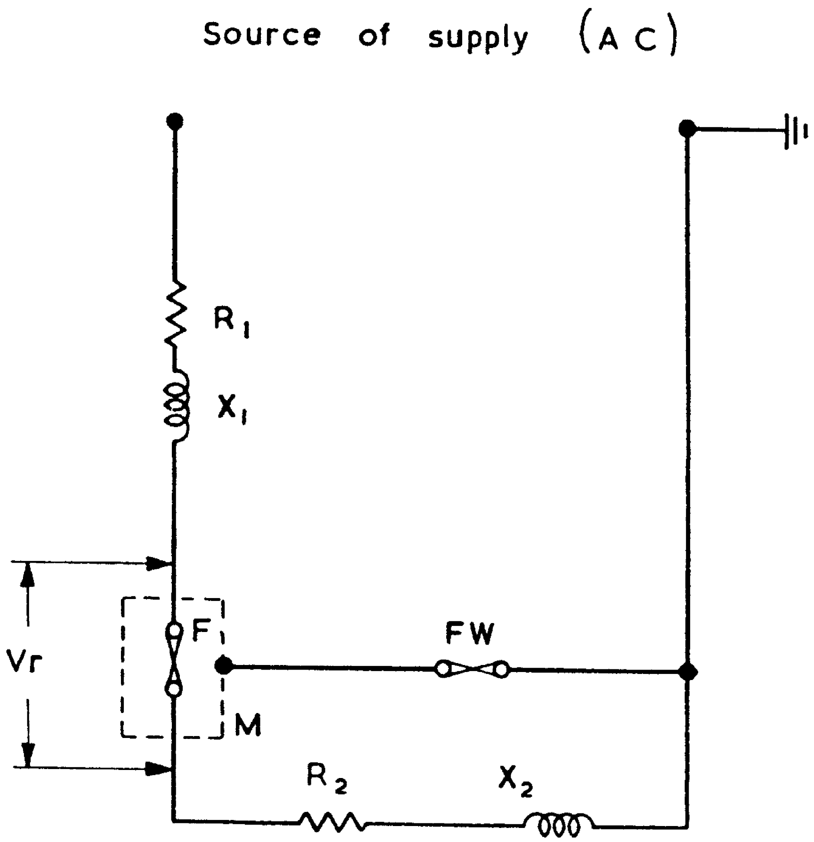
ii) Power factor.

iii) Number of fuses tested.

iv) Physical behaviour during test.

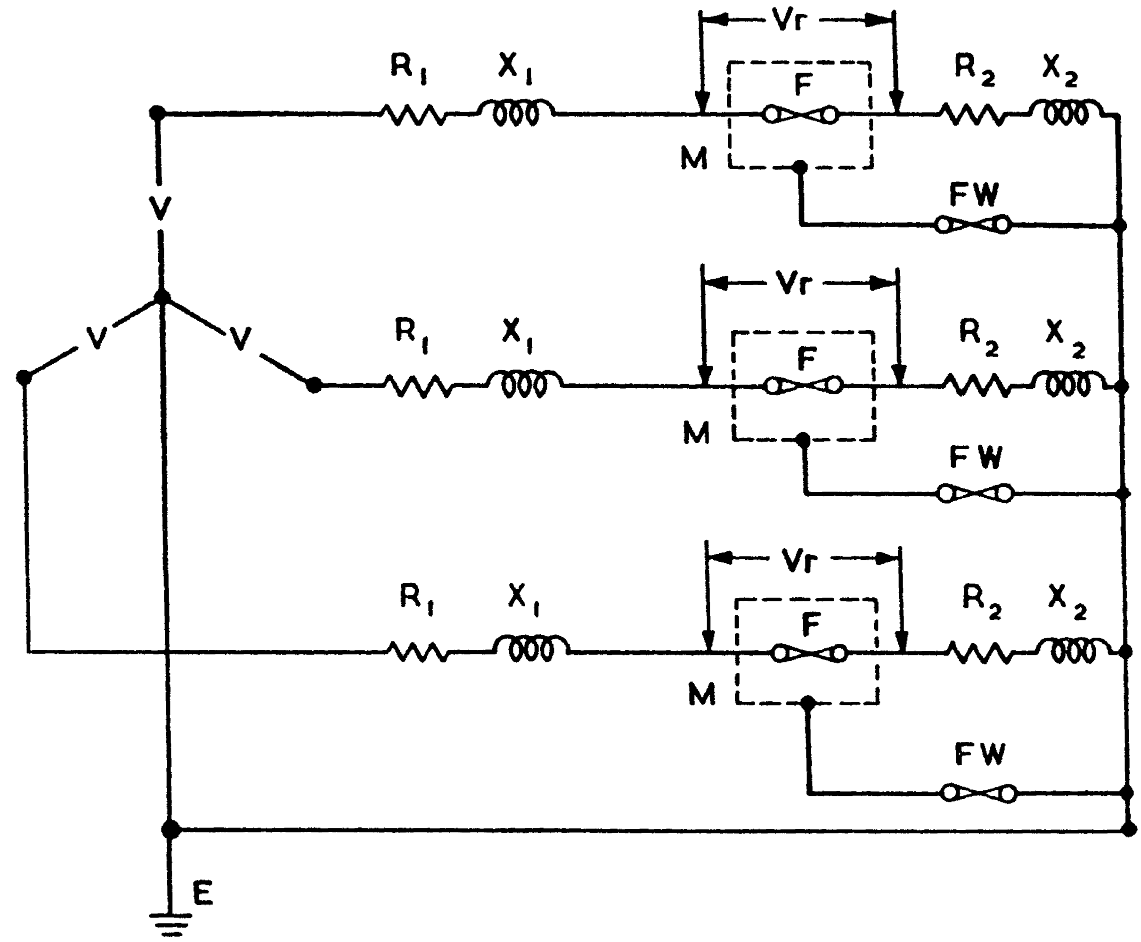
v) Physical condition after test.

vi) Lowest resistance after test.



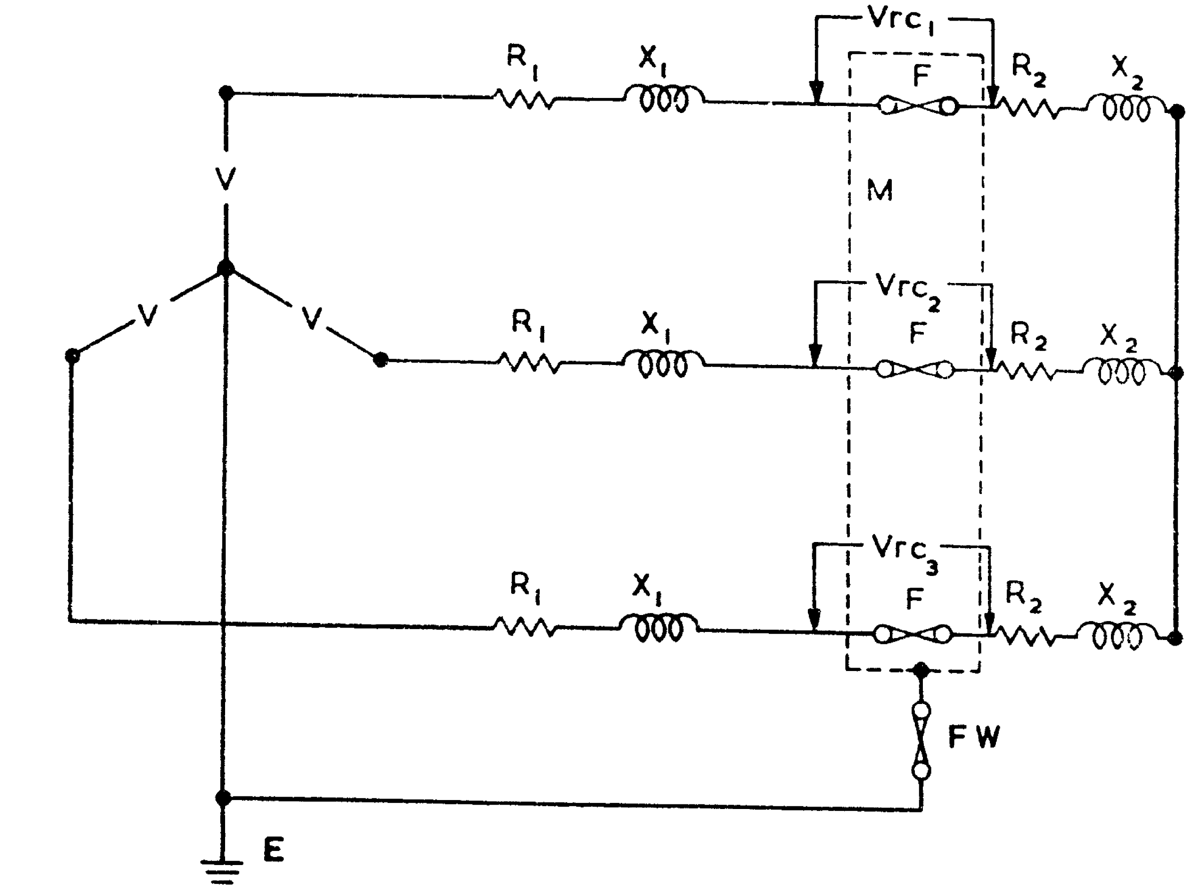
F = Fuse on test
M = Metal case
FW = Fine-wire fuse
Vr = Points at which recovery voltage is measured
R_1 X_1 = Resistor, and reactor as required for tests at full prospective current
R_2 X_2 = Resistor, and reactor for tests at reduced current

Figure 1 — Test circuit for fuses of 240-volt single-phase a.c. rating



V = Three-phase source of supply
F = Fuses on test
M = Metal case
FW = Fine-wire fuse
Vr = Points at which recovery voltage is measured
E = Earth connection
R_1 X_1 = Resistor and reactor as required for tests at full prospective current
R_2 X_2 = Resistor and reactor for tests at reduced current

Figure 2 — Alternative test circuit for fuses of 240-volt single-phase a.c. rating



V = Three-phase source of supply
F = Fuses on test
M = Metal case
FW = Fine-wire fuse
Vrc = Points at which recovery voltage is measured
E = Earth connection
R_1 X_1 = Resistor and reactor as required for tests at full prospective current
R_2 X_2 = Resistor and reactor for tests at reduced current

Figure 4 — Test circuit for fuses of 415-volt three-phase a.c. rating

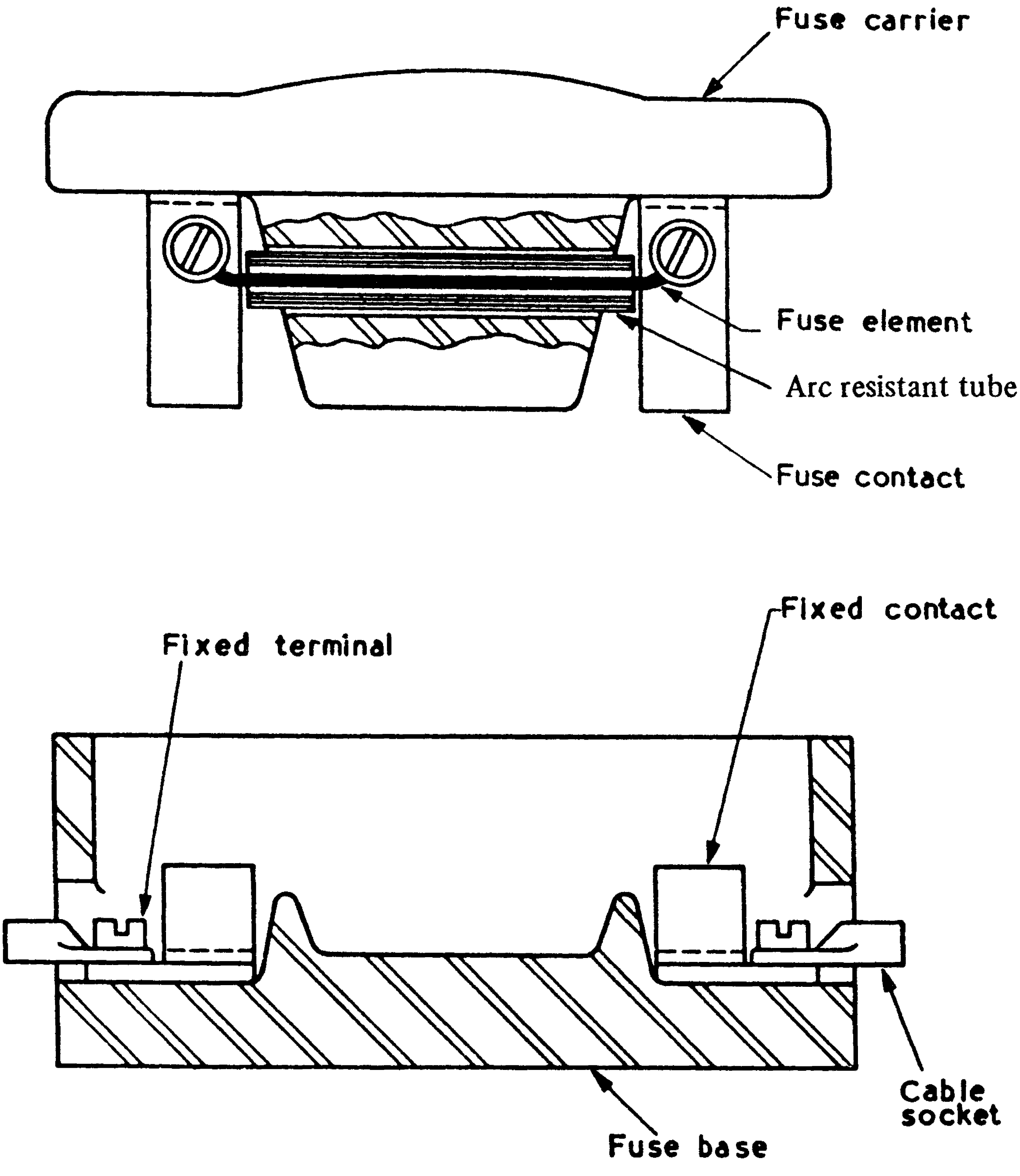


Figure 5 — Typical component parts of a semi-enclosed fuse

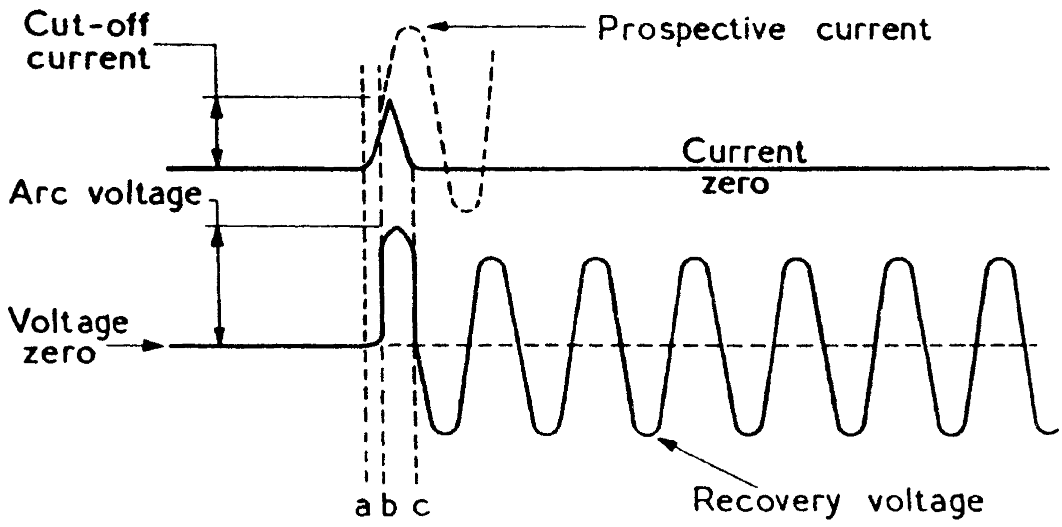


Figure 7 — Typical oscillogram of large prospective current in an a.c. circuit

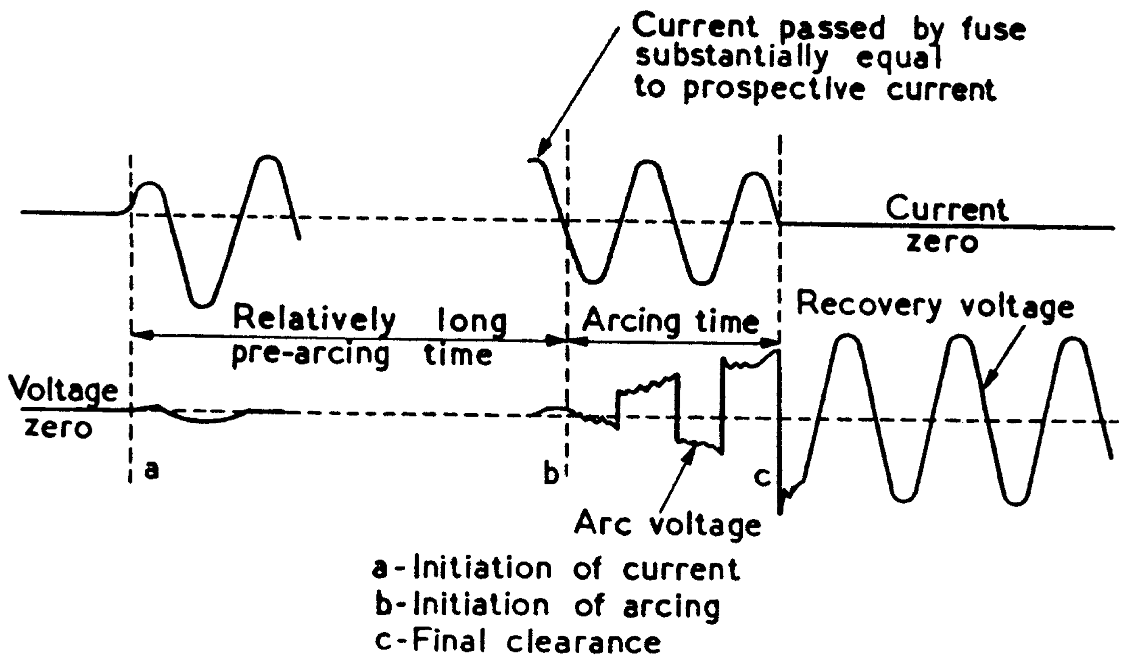


Figure 9 — Typical oscillogram of moderate prospective current in an a.c. circuit

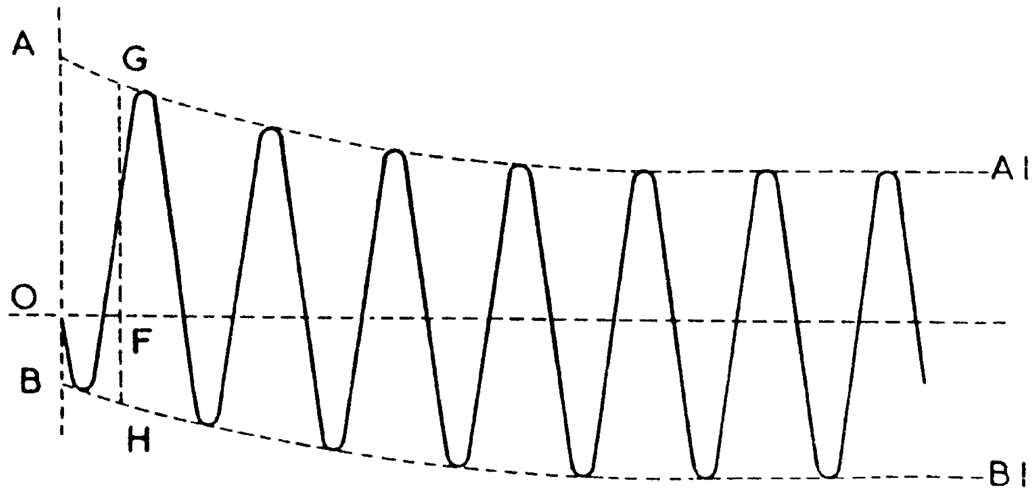


Figure 10 — Measurement of prospective current

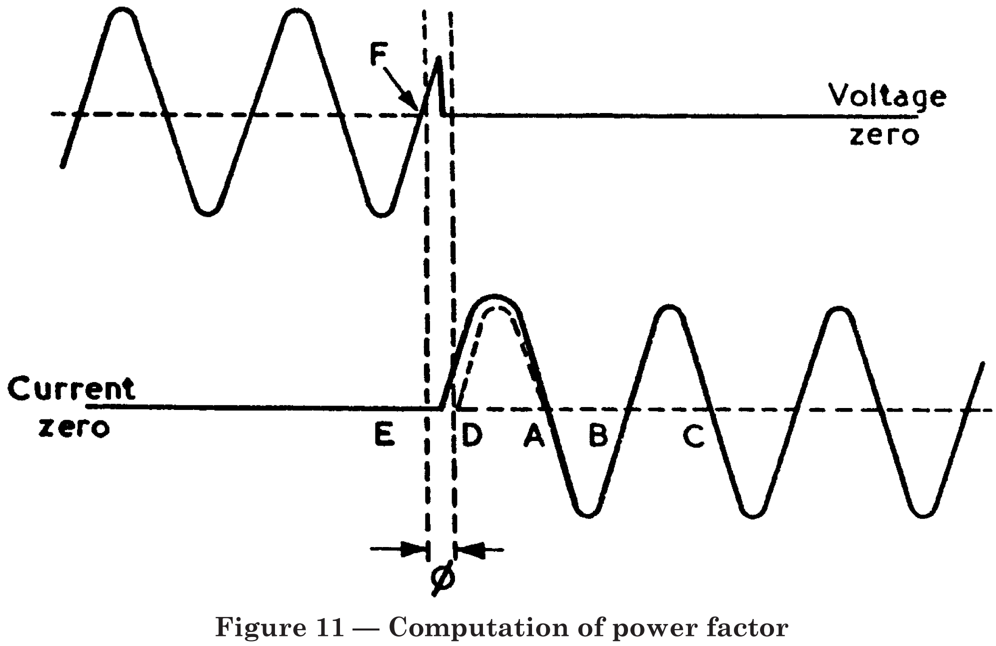


Figure 11 — Computation of power factor

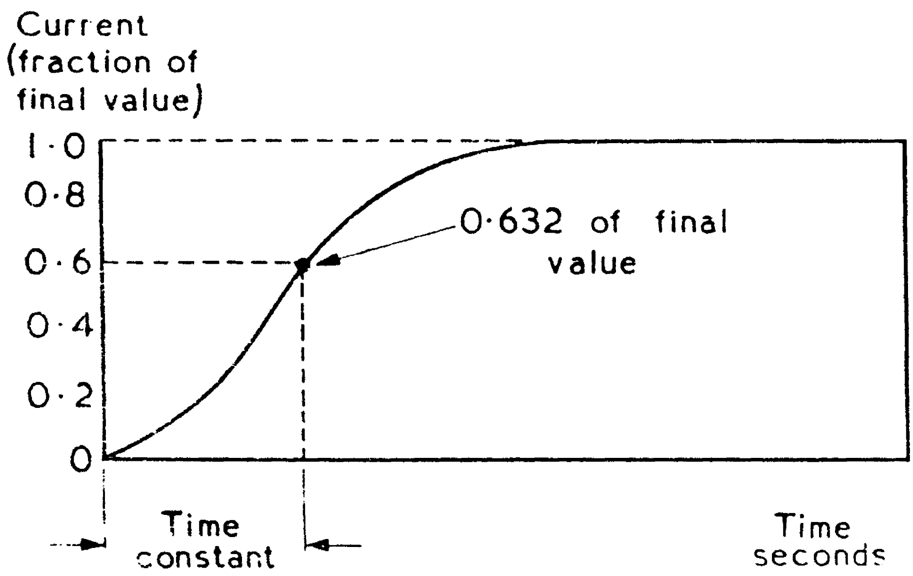


Figure 12 — Computation of time constant

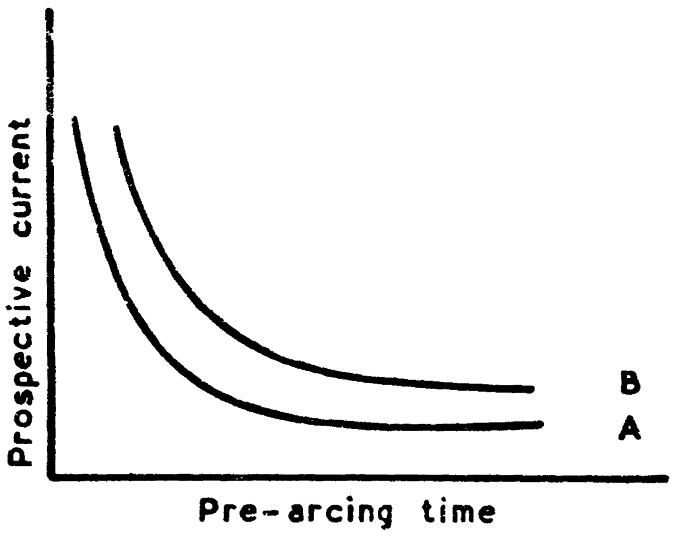


Figure 13 — Typical time/current characteristics of fuses of different current ratings

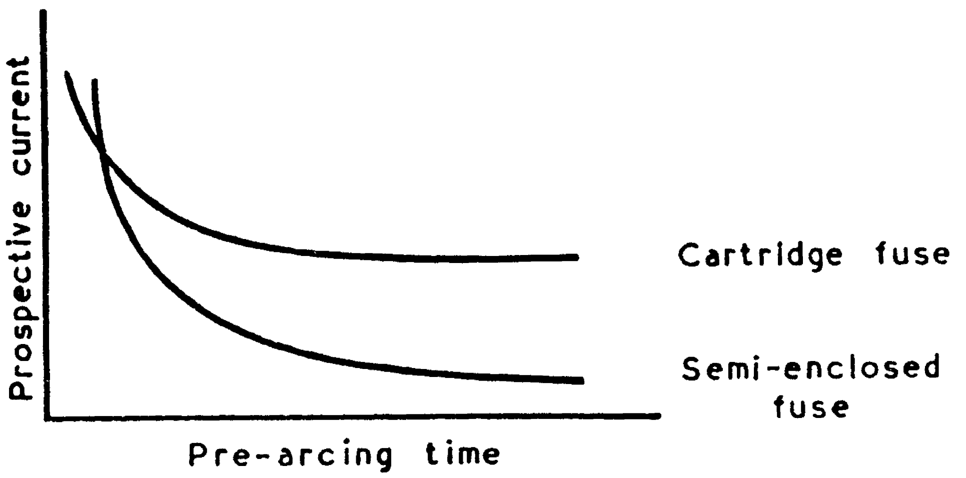


Figure 14 — Typical time/current characteristics of cartridge fuse and a semi-enclosed fuse of different current ratings

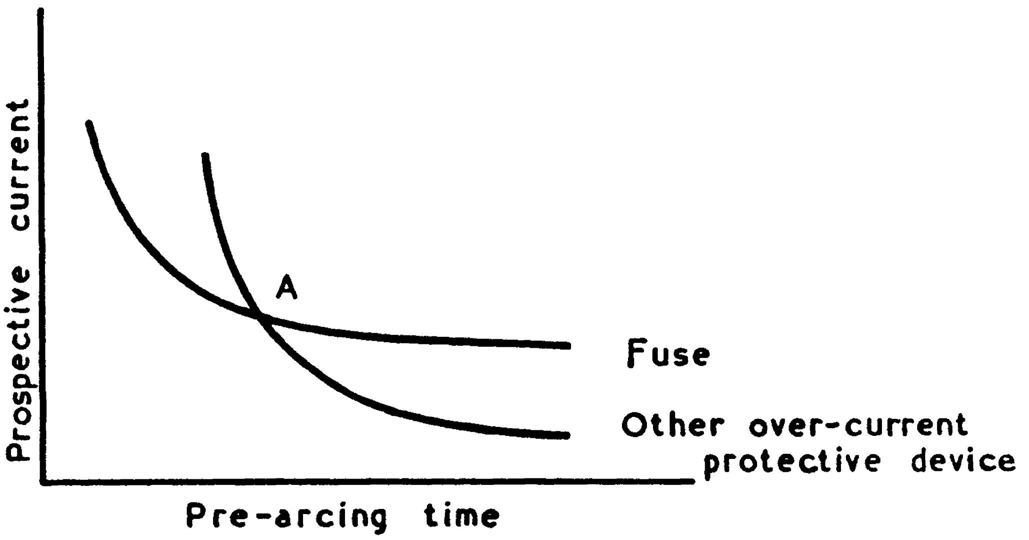


Figure 15 — Typical time/current characteristics of a fuse and some other over-current protective device

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