UL 248-1

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Low-Voltage Fuses – Part 1: General Requirements

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UL Standard for Safety for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1

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This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-30	August 1, 2000
A1-A6	August 1, 2000
B1-B16	August 1, 2000

National Association of Standardization and Certification of the Electrical Sector

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First Edition

CSA International

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Second Edition

Underwriters Laboratories Inc.

UL 248-1

Second Edition

Low-Voltage Fuses – Part 1: General Requirements

August 1, 2000

Commitment for Amendments

This Standard is issued jointly by the National Association of Standardization and Certification of the Electrical Sector (ANCE), the CSA International, and Underwriters Laboratories Incorporated (UL). Amendments to this Standard will be made only after processing according to the Standards writing procedures by ANCE, CSA, and UL.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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Preface

This is the common UL, CSA, and ANCE Standard for *Low-Voltage Fuses – Part 1: General Requirements*. It is the second edition of CSA C22.2 No. 248.1-00 (superseding the first edition, published in 1994), the second edition of UL 248-1, and the first edition of NMX-J-009/248/1-2000-ANCE.

This Standard was prepared by a Technical Harmonization Committee comprised of members from Underwriters Laboratories, CSA International, the National Association of Standardization and Certification of the Electrical Sector, the end product manufacturers, and material suppliers. The efforts and support of the members of the Technical Harmonization Committee are gratefully acknowledged.

This common Standard was prepared by the National Association of Standardization and Certification of the Electrical Sector, Canadian Standards Association, Underwriters Laboratories Inc., and the fuse industry of both the USA and Canada.

This Standard was reviewed by the CSA Subcommittee on Fuses and approved by the Technical Committee on Industrial Products under the jurisdiction of the CSA Strategic Resource Group.

This Standard will be submitted to the America National Standards Institute (ANSI) for publication as an American National Standard.

Note: Although the intended primary application of this Standard is stated in its scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

Level of Harmonization

This trinational standard is published as an Identical Standard. An identical standard is a standard that is the same in technical content except for conflicts in Codes and Governmental Regulations. Presentation is word for word except for editorial changes.

Interpretations

The interpretation by the SDO (Standards Development Organization) of an identical standard shall be based on the literal text to determine compliance with the standard in accordance with the procedural rules of the SDO. If more than one interpretation of the literal text has been identified, a revision shall be proposed as soon as possible to each of the SDOs to more accurately reflect the intent.

UL Effective Date

This edition of the standard is now in effect.

CSA Effective Date

The effective date for CSA will be announced through either a *CSA Informs* or *CSA Certification Notice*.

ANCE Effective Date

The effective date for ANCE will be announced through the *Diario Oficial de la Federation (Official Gazette)* and is indicated on the cover page.

Subsequent Parts

The Standard for Low-Voltage Fuses is divided into the following Parts:

Part No.	Fuse Class	Standard No.
1	General Requirements	NMX-J-009/248/1-2000-ANCE♦CSA C22.2 No. 248.1 ♦ UL 248-1
2	C	NMX-J-009/248/2-2000-ANCE♦CSA C22.2 No. 248.2 ♦ UL 248-2
3	CA and CB	NMX-J-009/248/3-2000-ANCE♦CSA C22.2 No. 248.3 ♦ UL 248-3
4	CC	NMX-J-009/248/4-2000-ANCE♦CSA C22.2 No. 248.4 ♦ UL 248-4
5	G	NMX-J-009/248/5-2000-ANCE♦CSA C22.2 No. 248.5 ♦ UL 248-5
6	H Non-renewable	NMX-J-009/248/6-2000-ANCE♦CSA C22.2 No. 248.6 ♦ UL 248-6
7	H Renewable	NMX-J-009/248/7-2000-ANCE♦CSA C22.2 No. 248.7 ♦ UL 248-7
8	J	NMX-J-009/248/8-2000-ANCE♦CSA C22.2 No. 248.8 ♦ UL 248-8
9	K	NMX-J-009/248/9-2000-ANCE♦CSA C22.2 No. 248.9 ♦ UL 248-9
10	L	NMX-J-009/248/10-2000-ANCE♦CSA C22.2 No. 248.10 ♦ UL 248-10
11	Plug	NMX-J-009/248/11-2000-ANCE♦CSA C22.2 No. 248.11 ♦ UL 248-11
12	R	NMX-J-009/248/12-2000-ANCE♦CSA C22.2 No. 248.12 ♦ UL 248-12
13	Semiconductor	NMX-J-009/248/13-2000-ANCE♦CSA C22.2 No. 248.13 ♦ UL 248-13
14	Supplemental	NMX-J-009/248/14-2000-ANCE♦CSA C22.2 No. 248.14 ♦ UL 248-14
15	T	NMX-J-009/248/15-2000-ANCE♦CSA C22.2 No. 248.15 ♦ UL 248-15
16	Test Limiters	NMX-J-009/248/16-2000-ANCE♦CSA C22.2 No. 248.16 ♦ UL 248-16

NOTES

1 Part 1 covers the general requirements for fuse characteristics, marking, construction, and tests. Additional requirements – such as dimensions, I^2t limits, and the like – pertaining to the various families of fuses are given in the subsequent Parts.

2 The subsequent Parts supplement or modify the corresponding Clauses in Part 1 and should be read together with Part 1. The numbering of Clauses in the subsequent Parts corresponds to like numbered Clauses in Part 1.

Foreword (ANCE)

The Present Mexican Standard was developed by the Low Voltage Fuses Subcommittee from the Comite de Normalizacion de la Asociacion Nacional de Normalizacion y Certificacion del Sector Electrico, A.C., CONANCE, with the collaboration of the fuse manufacturers and users.

ANCE is a National Organization for Standardization (ONN) registered by the DGN (Dirección General de Normas) in the electrical sector and household appliances which developes Mexican Standards (NMX) and collaborates in the development of the Mexican Official Standards (NOM), voluntary and mandatory standards, respectively.

The conformity assessment in accordance with ANCE Mexican Standards is responsibility of ANCE Certification Products Division.

The ANCE Certification Products Division is accredited by the EMA (Entidad Mexicana de Acreditación) in order to certificate a variety of products. The certification is carry out following the corresponding procedures established and developed by the Technical Committee of Certification in connection with the test reports performed in test labs accredited by the EMA.

The conformity assessment activities developed by ANCE cover quality systems, test lab and verification products.

Foreword (CSA)

The Canadian Standards Association, which operates under the name CSA International (CSA), provides certification services for manufacturers who, under license from CSA, wish to use the appropriate registered CSA Marks on certain products of their manufacture to indicate conformity with CSA Standards.

CSA Certification for a number of products is provided in the interest of maintaining agreed-upon standards of quality, performance, interchangeability and/or safety, as appropriate. Where applicable, certification may form the basis for acceptance by inspection authorities responsible for enforcement of regulations. Where feasible, programs will be developed for additional products for which certification is desired by producers, consumers or other interests.

In performing its functions in accordance with its objectives, CSA does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of the Association represent its professional judgement given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed.

Products in substantial accord with this Standard but which exhibit a minor difference or a new feature may be deemed to meet the Standard providing the feature or difference is found acceptable utilizing appropriate CSA Certification and Testing Division Operating Procedures. Products which comply with this Standard shall not be certified if they are found to have additional features which are inconsistent with the intent of this Standard. Products shall not be certifiable if they are discovered to contravene applicable laws or regulations.

Testing techniques, test procedures and instrumentation frequently must be prescribed by the CSA Certification and Testing Division in addition to the technical requirements contained in Standards of CSA. In addition to markings specified in the Standard, the CSA Certification and Testing Division may require special cautions, markings and instructions that are not specified by the Standard.

Some tests required by CSA Standards may be inherently hazardous. The Association neither assumes nor accepts any responsibility for any injury or damage that may occur during or as the result of tests, wherever performed, whether performed in whole or in part by the manufacturer or the Association, and whether or not any equipment, facility or personnel for or in connection with the test is furnished by the manufacturer or the Association.

Manufacturers should note that, in the event of the failure of the CSA Certification and Testing Division to resolve an issue arising from the interpretation of requirements, there is an appeal procedure: the complainant should submit the matter, in writing, to the Secretary of the Canadian Standards Association.

If this Standard is to be used in obtaining CSA Certification please remember, when making application for certification, to request all current Amendments, Bulletins, Notices and Technical Information Letters that may be applicable and for which there may be a nominal charge. For such information or for further information concerning CSA Certification please address your inquiry to Applications and Customer Service, CSA International, 178 Rexdale Boulevard, Toronto, Ontario M9W 1R3.

No Text on This Page

Foreword (UL)

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer’s product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

Low-Voltage Fuses – Part 1: General Requirements

1 General

1.1 Scope

1.1.1 This Standard applies to low-voltage fuses rated 1000 V or less, AC and/or DC, with interrupting ratings up to 200 kA. These fuses are intended to be used in accordance with the *Canadian Electrical Code, Part I* (CEC), and the *National Electrical Code*, NFPA 70 (NEC).

1.2 Object

1.2.1 This Standard and its subsequent Parts establish the characteristics, construction, operating conditions, markings, and test conditions for each of the fuse classes so that initial investigation and follow-up verification can be performed in an orderly manner.

2 Definitions

The following definitions apply in this Standard.

Note: The Clauses in Definitions, Clause 2*, are numbered corresponding to the Clause numbers for definitions for the similar items contained in the International Electrotechnical Commission, Publication 269-1: Low-voltage fuses, Part 1: General requirements. Some Clause numbers are omitted.*

2.1 Fuse

2.1.3 Fuse

A protective device which opens a circuit during specified overcurrent conditions by means of a current responsive element.

2.1.3.1 Body

The part of the fuse which encloses the fuse elements and supports the contacts. Also referred to as cartridge, tube, or case.

2.1.3.2 Filler

Material used to fill a section or sections of a fuse.

2.1.4 Contacts

The external metallic parts of the fuse used to complete the circuit. Also referred to as ferrules, caps, blades, or terminals.

2.1.5 Element

The fusible portion of the fuse which acts, during an overcurrent condition, to clear the circuit; also referred to as a link.

2.1.5.1 Renewal element

The part of a renewable fuse that is replaced after interruption to restore the fuse to operating condition.

2.2 General terms

2.2.2 Current-limiting fuse

A fuse that, within a specified overcurrent range, limits the clearing time at rated voltage to an interval equal to or less than the first major or symmetrical current loop duration; and limits the peak current to a value less than the available peak current.

2.2.5.1 Ambient temperature

The temperature of the air surrounding the fuse.

2.2.7.1 Low melting point fuse

A fuse that will open in an ambient temperature of 200°C when carrying 10 percent of rated current.

2.2.7.2 Microfuse

A supplemental fuse, the body of which has no principal dimension exceeding 10 mm (0.4 in), excluding the leads or terminals.

Note: Principal dimensions are length, width, height, and diameter.

2.2.7.3 Plug fuse

A screw-in type fuse for use in an Edison Base, Type C tamper-proof, or Type S tamper-proof fuseholder.

2.2.7.4 Renewable fuse

A fuse which can be restored for service, after interruption, by the replacement of the renewal elements.

2.2.7.5 Supplemental fuse

A fuse intended only for supplementary overcurrent protection where branch-circuit protection is not required.

2.2.7.6 Time-delay fuse

A fuse capable of carrying a specified overcurrent for a specified minimum time. Time-delay characteristics are verified by the overload and operation tests in the relevant subsequent Parts for certain fuse classes.

2.2.7.7 Branch circuit fuse

A fuse which is suitable for protection of distribution systems, wiring, or equipment. Examples of branch circuit fuses are Classes R, J, L, T, and CC. A supplemental fuse, intended to protect equipment only, is not a branch circuit fuse.

2.2.8 Body size

The specified set of dimensions of fuses within a fuse class or system. Each individual size covers a given range of rated currents for which the specified dimensions of the fuse remain unchanged.

2.2.9 Homogeneous series of fuses

A series of fuse current ratings, within a given body size and of similar construction, such that one of the ratings of the series may be taken as representative of the series itself.

2.2.13 Non-interchangeability

A condition which prevents the inadvertent interchange of fuses because of physical characteristics (slot, groove, pin, overall dimensions, and the like).

2.3 Characteristic quantities

2.3.2 Prospective current

The current that would flow in a circuit if a fuse therein were replaced by a shorting bar of negligible impedance. The prospective current is also referred to as the available current and is the quantity to which the interrupting rating, I^2t, and peak let-through current are normally referred.

2.3.4 Interrupting rating

The highest prospective rms symmetrical alternating current or direct current which a fuse will interrupt under specified conditions verified by operation at rated voltage tests.

2.3.4.1 Maximum energy

A specified test condition which causes a fuse to experience maximum arc energy during interruption within the first 1/2 cycle.

2.3.5 Current-limiting range

The range of prospective currents from the threshold current to the interrupting current rating of a fuse.

2.3.5.1 Threshold current

The lowest prospective rms symmetrical current above which a fuse is current limiting.

2.3.5.2 Threshold ratio

The threshold current divided by the fuse current rating.

2.3.6 Peak let-through current (I_p)

The maximum instantaneous current through a fuse during interruption in its current-limiting range.

2.3.9 Melting time

The time from the initiation of a specified overcurrent to the instant when arcing of the element begins.

2.3.10 Arcing time

The time from the instant the fuse element or link has melted and arcing is initiated, until final circuit interruption by the fuse.

2.3.11 Clearing time

The time from the beginning of an overcurrent to final circuit interruption by the fuse. The clearing time is equal to the sum of the melting time and the arcing time.

2.3.12 I^2t (ampere-squared seconds)

A measure of heat energy developed during fuse interruption from the initiation of an overcurrent until the fuse clears the circuit. ″I^2″ stands for the square of the effective (rms) let-through current and ″t″ stands for the time of current flow in seconds. The term I^2t also applies during the melting or arcing portions of the clearing time and is referred to as melting or arcing I^2t respectively. Clearing I^2t is the sum of melting I^2t and arcing I^2t.

2.3.15 Current rating (I_n)

The nominal rms AC or DC ampere rating, based on specified conditions, which is assigned to a fuse.

2.3.15.1 Voltage rating

The nominal rms AC and/or DC voltage for which a fuse is designed.

2.3.18 Conventional non-fusing current (I_{nf})

A specified current which a fuse is capable of carrying under specified conditions without opening.

2.3.18.1 Conventional time

A specified time within which a fuse must open (or carry current) during a conventional current test.

2.3.19 Conventional fusing current (I_f)

The lowest specified current which causes a fuse to open within a specified (conventional) time.

2.3.23 Recovery voltage

The power frequency rms or DC voltage impressed upon the fuse after the circuit has been interrupted and after high frequency transients have subsided.

2.3.24 Peak arc voltage

The maximum instantaneous voltage across the fuse during the arcing time.

3 Service conditions

The requirements of this Standard are based on fuses being used in a clean and dry environment under normal ambient temperature conditions. The manufacturer should be consulted if fuses are to be used in extreme conditions.

4 Classification

The low-voltage fuses covered by this Standard and the subsequent Parts are classified according to dimensions, interrupting rating, and electrical characteristics. A letter class designation system is used which covers most fuses included in this Standard and which identifies specific dimensions and short circuit performance characteristics.

5 Characteristics

5.1 Summary of Characteristics

The following terms identify the characteristics of fuses covered by this and the subsequent Parts:

a) voltage rating;

b) current rating;

c) frequency rating;

d) AC and/or DC;

e) interrupting rating;

f) peak let-through current; and

g) clearing I^2t.

5.2 Voltage rating

For AC, the preferred values of voltage are 125, 250, 300, 480, or 600 V ac as specified for the particular fuse class.

For DC, the preferred values of voltage are 60, 125, 160, 250, 300, 400, 500, or 600 V dc.

5.3 Current rating

Typical current ratings are: 1/10, 15/100, 2/10, 3/10, 4/10, 1/2, 6/10, 8/10, 1, 1-1/8, 1-1/4, 1-4/10, 1-6/10, 1-8/10, 2, 2-1/4, 2-1/2, 2-8/10, 3, 3-2/10, 3-1/2, 4, 4-1/2, 5, 5-6/10, 6, 6-1/4, 7, 8, 9, 10, 12, 15, 17-1/2, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, 6000 A.

5.4 Frequency rating

The AC frequency rating shall be 48 – 62 Hz.

5.5 Interrupting rating

The AC interrupting rating of a fuse under specified conditions correlates to and is in accordance with the fuse classification.

The preferred DC interrupting ratings are 10,000, 20,000, 50,000, 100,000, 150,000, or 200,000 A.

5.6 Peak let-through current and clearing I^2t characteristics

The peak let-through current and clearing I^2t characteristics of a fuse correlate to and are in accordance with the fuse classification.

6 Marking

6.1 Marking of fuses

The information on a fuse shall be legible and include the following, with the corresponding unit of measurement:

a) the manufacturer’s name, trademark, or both;

b) current rating;

c) voltage rating;

d) interrupting rating in rms symmetrical and/or DC amperes;

e) the appropriate fuse class or classification;

f) ″Time Delay″ (for qualifying fuses only); and

g) ″Current Limiting″ (for qualifying fuses only).

Note: Except for supplemental fuses, markings ″D″ and ″P″ are to be reserved exclusively for use with low melting point fuses.

6.2 Marking symbols

Preferred symbols are:

Unit of Measurement	Preferred Symbol
volts	V
amperes	A
kiloamperes	kA
milliamperes	mA
interrupting rating	IR or I_1
alternating current	⎓ (IEC 417 No. 5032-a)
direct current	∿ (IEC 417 No. 5031-a)
alternating & direct current	⏦ (IEC 417 No. 5033-a)
cycles per second	Hz

7 Construction

7.1 Dimensions

Dimensions shall be held to the tolerances specified in the dimension table in the relevant subsequent Parts.

7.2 Current-carrying parts

Current-carrying parts shall be made of copper, brass, or other non-ferrous metal.

7.3 Connections

Connections between the element and the contacts of a fuse shall maintain permanent electrical contact. The connection shall be soldered, brazed, welded, or otherwise made permanently secure.

7.4 Adhesives

An adhesive employed in a fuse shall adequately secure together the intended parts as demonstrated during the test program.

7.5 Contact alignment

Contacts shall be held in substantial alignment by means other than friction between surfaces, unless the press-fitted assembly is not subject to shrinkage or warping due to heat or moisture.

7.6 Body

The body of a fuse shall be glass, ceramic, melamine, impregnated glass fiber, or vulcanized fiber. Other materials may be used that are shown by investigation to be acceptable for the purpose.

7.7 Corrosion protection

Iron and steel parts shall be protected against corrosion.

8 Tests

8.1 General

8.1.1 Types of tests

The highest current rating of each homogeneous series of fuses shall be subjected to the following tests:

a) verification of temperature rise and current-carrying capacity;

b) verification of overload operation;

c) verification of operation at rated voltage; and

d) verification of peak let-through current and clearing I^2t.

The number of fuses to be tested is shown in Table 1.

Note: If the body material is other than indicated in Clause 7.6, two sets of samples are to be used for rated voltage tests; one set is to be conditioned in accordance with footnote (e) and the other set in accordance with footnote (f), of Table 5.

8.1.2 Ambient air temperature

The ambient air temperature shall be measured by measuring devices protected against drafts and heat radiation, placed at the height of the center of the fuse and at a distance of approximately 1 m (3 ft). At the beginning of each test, the fuse shall be within ±5°C of the ambient air temperature.

8.1.3 Condition of the fuse

Tests shall be made on fuses in a clean and dry condition.

8.1.4 Arrangement of the fuse and dimensions

The fuse shall be mounted in free air in draft-free surroundings in the horizontal position and, unless otherwise specified, on insulating material of sufficient rigidity to withstand the forces encountered without applying external load to the fuse under test.

The fuse shall be mounted as in normal use, in a fuseholder for which it is intended, or in a test rig in accordance with the requirements in the relevant Clause in a subsequent Part.

Before the tests are started, the specified external dimensions shall be measured and the results compared with the dimensions specified in the relevant data sheets of the manufacturer or specified in the relevant subsequent Parts.

Table 1 – Number of fuses to be tested (may be modified by subsequent Parts)

Test	Current rating I_n, A		
	0 – 100	101 – 600	601– 6000
8.2 Verification of temperature rise and I_{nf}	3	3	1
8.3 Verification of overload operation			
a) t_{max} (1.35 I_n)	3	2	–
b) t_{max} (1.5 I_n)	–	–	1
c) t_{max} (2 I_n)	2	2	–
d) t_{min} (2 I_n)	1	–	–
e) t_{min} (5 I_n)	1	1	–
8.4 Verification of operation at rated voltage			
a) 2 I_n or 3 I_n	1	1	1
b) 9 I_n (DC only)	1	1	1
c) 10 kA	1	1	1
d) 50 kA	1	1	1
e) 100 kA	1	1	1
f) 200 kA	1	1	1
g) maximum energy	1	1	1
h) threshold ratio	1	1	1
8.5 Verification of peak let-through current and clearing I^2t shall be combined with Test 8.4 (d, e, f, and g)	–	–	–

8.2 Verification of temperature rise and current-carrying capacity

8.2.1 Arrangement of the fuse

8.2.1.1 Fuses rated 600 A or less

Each fuse shall be supported in the intended manner in a single pole fuseholder. Each fuseholder shall be mounted horizontally on a bench or test board of non-conducting material that is so arranged that each fuse under test shall have its major axis horizontal.

If a test board is designed for the testing of two or more fuses in series, the fuseholders shall be so located that there will be a spacing of not less than 152 mm (6 in) between any two fuses under test. The fuseholders and any current measuring devices connected directly to the test circuit shall be connected to each other and to the source of supply by means of copper wire, as specified in Table 2.

Table 2 – Temperature test connections

Fuse current ratings I_n, A	Minimum length[a], m (ft)	Wire size, AWG or kcmil (mm^2)
0 – 30	0.6 (2)	8 (8.4)
31 – 60	0.6 (2)	4 (21.2)
61 – 100	0.6 (2)	1 (42.4)
101 – 200	0.6 (2)	4/0 (107.2)
201 – 400	1.2 (4)	500 (253)
401 – 600	1.2 (4)	1000 (507)

[a] Any connection to the source of supply shall not be less than 1.2 m (4 ft) long.

A conductor larger than 8 AWG (8.4 mm^2) shall be connected by a soldering lug or pressure wire connector.

The fuse shall be mounted in fuse clips or bolted in position. For fuses rated over 60 A, utilizing fuse clips, clamps shall be permitted to press the fuseholder terminals against the knifeblade terminals of the fuse. Each clamp shall weigh not more than 85 g (3 oz) and neither of the 2 faces of the clamp making contact with the fuseholder terminals shall have an area greater than 323 mm^2 (1/2 in^2).

8.2.1.2 Fuses rated 601 – 6000 A

The major axis of the fuse shall be horizontal. Each terminal of the fuse shall be connected to a copper bus bar that is silver plated at points of contact with the fuse. Each bus bar shall be rectangular in cross section and not exceed the area shown in Table 3. The bus bar shall be at least as wide as the fuse terminal. Mounting screw holes shall be provided in the bus bar to correspond with those of the fuse to be tested.

Table 3 – Bus bar cross section and shorting bar temperature rises

Fuse current ratings I_n, A	Maximum bus bar cross section, cm^2 (in^2)	Shorting bar temperature rise above room ambient,°C	
		Minimum	Maximum
601 – 800	4.84 (3/4)	20	35
801 – 1200	6.45 (1)	20	35
1201 – 1600	12.9 (2)	20	35
1601 – 2000	19.4 (3)	20	35
2001 – 2500	25.8 (4)	20	35
2501 – 3000	29.0 (4-1/2)	30	45
3001 – 4000	38.7 (6)	40	60
4001 – 5000	58.1 (9)	50	70
5001 – 6000	58.1 (9)	65	85

8.2.2 Test circuit characteristics

8.2.2.1 Power supply

A 48 – 62 Hz AC test circuit of any convenient voltage shall be used. A DC test circuit may be used if no ferrous metal other than bolts, nuts, or other small assembly parts are employed in the fuse.

8.2.2.2 Ambient air temperature

The ambient temperature shall not vary more than 5°C during the test and shall be within the limits of 25 ± 5°C.

8.2.3 Test method

The current carrying capacity test, which confirms the conventional non-fusing current, I_{nf}, is conducted as part of the temperature rise test.

Measurement of temperatures shall be by thermocouples. The thermocouples shall be secured by Fuller's earth and waterglass, welding, soldering, or other method that provides thermal contact.

The thermocouples shall consist of iron and constantan or chromel and alumel wires not larger than No. 24 AWG (0.21 mm^2).

An alternative method of temperature measurement may be used if upon investigation it is shown that the alternative method provides equivalent results.

8.2.3.1 Fuses rated 600 A or less

Fuses rated 600 A or less shall carry 1.0 I_n until temperature stabilization occurs.

Stabilization shall be considered to have occurred when no individual temperature rise reading of 4 consecutive readings taken at 5 min intervals exceeds the average reading of these 4 readings by more than 2°C and no indication of increasing temperature rise is observed. This average temperature rise reading shall be deemed to be the temperature rise of the fuse.

Thermocouples shall be placed against the center of the top or upper surface of the fuse – midway between the caps or ferrules on the body and on each ferrule or blade at the top center of the fuse clip.

8.2.3.2 Fuses rated 601 – 6000 A

Fuses rated more than 600 A shall carry 1.1 I_n until temperature stabilization occurs.

Stabilization shall be considered to have occurred when no individual temperature rise reading of 4 consecutive readings taken at 10 min intervals exceeds the average reading of these 4 readings by more than 2°C and no indication of increasing temperature rise is observed. This average temperature rise reading shall be deemed to be the temperature rise of the fuse.

The test equipment shall be calibrated, with a shorting bar substituted for the fuse to be tested, to produce a temperature rise on the shorting bar within the limits specified in Table 3.

The shorting bar shall be the same length as the fuse for which it is substituted. The cross-sectional dimensions of the shorting bar shall be the same as those of the bus bar. The shorting bar shall be of copper, shall be silver-plated at the terminal connections, shall have holes to permit mounting to the bus bar, and shall be one-piece or laminated without space between the laminations.

During calibration, a thermocouple shall be located at the top center of the shorting bar.

During the temperature test, a thermocouple shall be secured at the top center of each fuse contact, approximately 6.4 mm (1/4 in) from the end of the fuse body.

8.2.4 Acceptability of test results

No external soldered connections shall melt. The fuse body or label may discolor but shall not char nor rupture in any manner and shall be readily identifiable for replacement purposes.

The temperature rise limits specified in the relevant subsequent Parts shall not be exceeded.

Fuses shall not open during this test.

8.3 Verification of overload operation

8.3.1 Arrangement of fuse

The arrangement of the fuse shall be as specified in arrangement of the fuse, Clause 8.2.1.

8.3.2 Test circuit

The test circuit shall be as specified in Test circuit characteristics, Clause 8.2.2.

8.3.3 Test method

Fuses are to be tested singly or a number of fuses not exceeding three may be tested in series.

8.3.3.1 Overload test

The overload tests are conducted on a preset circuit or the current is to be adjusted to the required test current, within 3 s, at a uniform rate.

8.3.3.2 Time-delay test

The time-delay test is to be conducted on a preset circuit adjusted to the required test current using a copper bar equivalent to the fuse contact dimensions in the circuit. The copper bar is then to be replaced with the test fuse, the circuit turned on, and readjusted to the required test current, within 3 s, at a uniform rate.

8.3.4 Acceptability of test results

A fuse shall operate according to the time limits specified in Table 4.

No external soldered connections shall melt. The fuse body or label may discolor but shall not char nor rupture in any manner and shall be readily identifiable for replacement purposes.

Table 4 – Verification of overload operation

Current rating I_n, A	Overload maximum clearing time (t_{max}), min			Time delay minimum clearing time (t_{min}), s	
	Test number				
	1	2	3	4	5
	Test current				
	1.35 I_n	1.5 I_n	2.0 I_n	2.0 I_n	5.0 I_n
0 – 30	60	–	4	12	10
31 – 60	60	–	6	12	10
61 – 100	120	–	8	–	10
101 – 200	120	–	10	–	10
201 – 400	120	–	12	–	10
401 – 600	120	–	14	–	10
601 – 800	–	240	–	–	–
801 – 1200	–	240	–	–	–
1701 – 1600	–	240	–	–	–
1001 – 2000	–	240	–	–	–
2001 – 2500	–	240	–	–	–
2501 – 3000	–	240	–	–	–
3001 – 4000	–	240	–	–	–
4001 – 5000	–	240	–	–	–
5001 – 6000	–	240	–	–	–

8.4 Verification of operation at rated voltage

8.4.1 Arrangement of the fuse

The fuse shall be mounted as in normal use, in a fuseholder for which it is intended, or in a test rig. The fuse may be mounted in a vertical or horizontal position. Before commencing tests the specified external dimensions of the fuse shall be measured and recorded (see Clause 8.4.4,(d)).

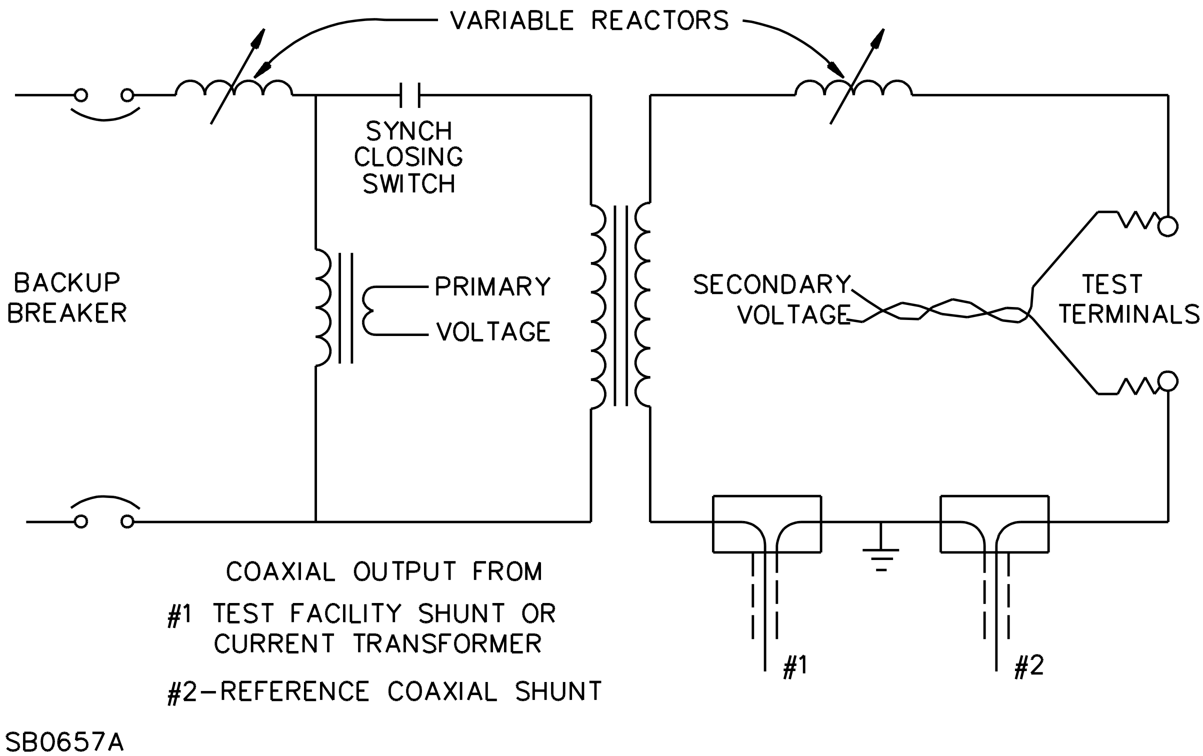
In order to confirm that the interrupting capacity is not less than the interrupting rating, no additional impedance shall be added to the test circuit.

8.4.2 Test circuit characteristics

The test circuit shall be single phase, having the characteristics specified in Table 5.

The test circuit is shown by way of example in Figure 1.

Figure 1 – Typical test circuit



The energy source is protected by a suitable circuit protective device; the test circuit characteristics shall be adjusted by a series arrangement of adjustable resistors and adjustable reactors. The circuit shall be closed by suitable switches. A means of controlled closing shall be provided, if required.

8.4.2.1 For AC circuits

The tests shall be made at a frequency of 48 – 62 Hz.

The inductors shall be air core type. Inductors may be series or parallel connected and resistors may also be series or parallel connected, but inductors and resistors may not be parallel connected.

The peak value of power frequency recovery voltage from the first full half cycle after clearing and for the next three successive peaks shall correspond to the peak value pertaining to the rms value specified in Table 5.

Table 5 – Verification of operation at rated voltage for AC

Test	High current	Maximum energy	Threshold ratio	Intermediate current			Low current	
Test No.	1	2	3	4a	4b	4c	5a	5b
Current	200 kA	a	b	100 kA	50 kA	10 kA	3 I_n	2 I_n
Tolerance	+ 10 percent - 0 percent	Not applicable		+ 10 percent - 0 percent			+ 20 percent - 0 percent	
Power factor	0.2 max.					0.45 to 0.5	0.8 max.	
Arcing angle[c]	60°– 90°		Not specified	60° – 90°		Random closing – No oscillographic records required		
Closing angle	Not specified		approx. 90°0	Not specified				
Recovery voltage[d]	Rated voltage + 5 percent, - 0 percent						Rated +20 percent voltage - 0 percent	
Duration of recovery voltage	30s		Not specified	30s			60s	
Maximum arc voltage	3000 V							
Pre-conditioned	e Yes	f Yes	e Optional	e Yes		No	e Optional	

[a] Only required if less than the assigned interrupting rating of the fuse.

For maximum energy tests the available current is to be adjusted such that the peak current at interruption is 70 – 100 percent of the peak value of the rms current. This test in not required for ratings of less than 30 A, if they employ the same filler as the 30 A fuses. Fuses rated 1 A or less, that do not employ a filler, are represented by the 30 A rating.

[b] Test current shall be equal to or less than the product of the fuse rating in A times the threshold ratio (TR), specified for the fuse under test.

[c] If start of arcing cannot be obtained, then test at closing angle essentially at zero.

[d] The recovery voltage may exceed +5 percent with the manufacturer's agreement.

[e] Each fuse is to be tested within 1 h of removal from a 90 ± 3°C oven after at least 24 h of conditioning.

Exception: Oven conditioning is not required on fuses with tubing material of glass, ceramic, melamine impregnated glass fiber, or equivalent non-hygroscopic material, when the fuse employs a sand filler or no filler.

[f] The fuse is to be tested within 1 h of removal from a humidity cabinet, after conditioning at room temperature 25°C and 90 – 100 percent relative humidity for 5 d.

8.4.2.2 For DC tests

The tests shall be made with DC in an inductive circuit with series resistance for the adjustment of available current. The inductors may be series and parallel connected, and may be iron cored, provided they do not saturate during the test.

Time constants shall be as specified in Table 6 or in the relevant subsequent Parts.

The mean value of the DC recovery voltage during the 100 ms after final arc extinction shall not be less than the value specified in Table 6 or the relevant subsequent Parts.

Table 6 – Verification of operation at rated voltage for DC

Test	**High current**	**Maximum energy**	**Low current**		
Test No.	1	2	5a	5b	5c
Current	≥ 10 kA	[a]	9 I_n	3 I_n	2 I_n
Tolerance	+ 10 percent - 0 percent	Not Applicable	+ 20 percent - 0 percent		
Time constant	≥ 10 ms		≥ $0.5(I_{test})^{0.3}$ ms[b]		
Recovery voltage	Rated voltage + 5 percent - 0 percent		Rated + 20 percent voltage - 0 percent		
Duration of recovery voltage	30 s	Not specified	60 s		
Pre-conditioned	Optional[c]	Yes[d]	Optional[c]		

[a] Only required if less than the assigned interrupting rating of the fuse.

For maximum energy tests, the peak current shall be between 0.6 and 0.8 of the available current. The circuit shall be adjusted to obtain this result. This test is not required for ratings of less than 30 A if they employ the same filler as the 30 A fuse.

[b] Not greater than 10 ms unless agreeable to those concerned.

[c] Each fuse is to be tested within 1 h of removal from a 90°C oven after at least 24 h of conditioning.

[d] The fuse is to be tested within 1 h of removal from a humidity cabinet, after conditioning at room temperature 25°C and 90 – 100 percent relative humidity for 5 d.

8.4.2.3 Calibration of test circuit

The test circuit shall be calibrated as specified in Appendix A.

8.4.2.4 Measuring instrumentation

The measurement of test parameters – current, voltage, and time for example – shall be made in accordance with Appendix B, or with electronic systems that have been shown to be equivalent to these methods.

8.4.3 Test method

To verify performance, one fuse at a time shall be tested in accordance with Table 5 for AC and Table 6 for DC.

8.4.3.1 Tests 1, 2, 3, 4a, 4b

If the available current for any test is greater than the interrupting rating, then the test is waived. For AC tests 1, 4a, 4b the closing angle of the test circuit shall be between 0° and 90° on the voltage wave.

For AC test 3, the closing angle shall be 90° or later, with reference to the voltage wave.

8.4.3.2 Tests 5a, 5b, 5c

The fuse may be pre-heated by means of a reduced voltage circuit. This current shall be within ± 20 percent of the required test current. The switchover to the test circuit shall be before the arc is initiated. (The switching time should not exceed 1.0 s).

At least one full cycle (or at least 17 ms) of current at rated voltage shall flow before arcing starts.

The time required for the fuse to clear and the duration of arcing are not specified.

8.4.4 Acceptability of test results

The fuse shall operate and permanently clear the circuit without damage to the components of the complete fuse within the following parameters:

a) there shall be no re-establishment of current. If evidence of a tendency to restrike is noted, application of the recovery voltage shall be continued for 60 s past the time of restrike;

b) the fuse shall not emit molten metal;

c) no external soldered connections shall melt;

d) the fuse shall not exhibit movement nor deformation of either or both end caps that would result in more than 3.2 mm (0.125 in) increase in overall length;

e) there shall be no holes in the fuse as a result of this test;

f) the fuse body may discolor but shall be readily identifiable for replacement purposes;

g) for fuses with glass or ceramic bodies, cracking of the body is permissible provided that the fuse remains in one piece, without loss of filler, prior to removal from the holder or test rig; and

h) for the threshold test, fuses shall clear in the first half cycle after closing.

Should non-conforming performance be encountered during the operation at rated voltage tests, and the performance is attributed to a test condition that is within the limits indicated for the test, but more severe than necessary, such as higher than rated voltage, three additional fuses may be tested. The fuses shall be of the same design and rating, and subjected to the same test that resulted in non-conforming performance. The circuit is to be readjusted closer to the rating, power factor or time constant, and the like, in a manner acceptable to those concerned. If there is an additional non-conforming performance, the overall results of this test is considered non-conforming.

8.5 Verification of peak let-through current and clearing I^2t characteristics

8.5.1 Test method

The fuse peak let-through current and clearing I^2t shall be evaluated from the results obtained from verification of operation at rated voltage, Clause 8.4, when tested on circuits having available currents above the threshold currents.

8.5.2 Measuring instrumentation

The measurement of peak let-through current and clearing I^2t, may be made by measurement of the oscillogram or by equivalent electronic systems. The oscillogram may be enlarged for greater accuracy. See Appendix B for the methods to be employed.

8.5.3 Acceptability of test results

The peak let-through current and clearing I^2t shall be within the limits specified in the relevant subsequent Parts.

Appendix A

Circuit calibration for interrupting rating tests

A1 Galvanometers

If a magnetic oscillograph is employed for recording voltage and current during circuit calibration and while testing high interrupting rated fuses, the galvanometer that is used shall have the following characteristics:

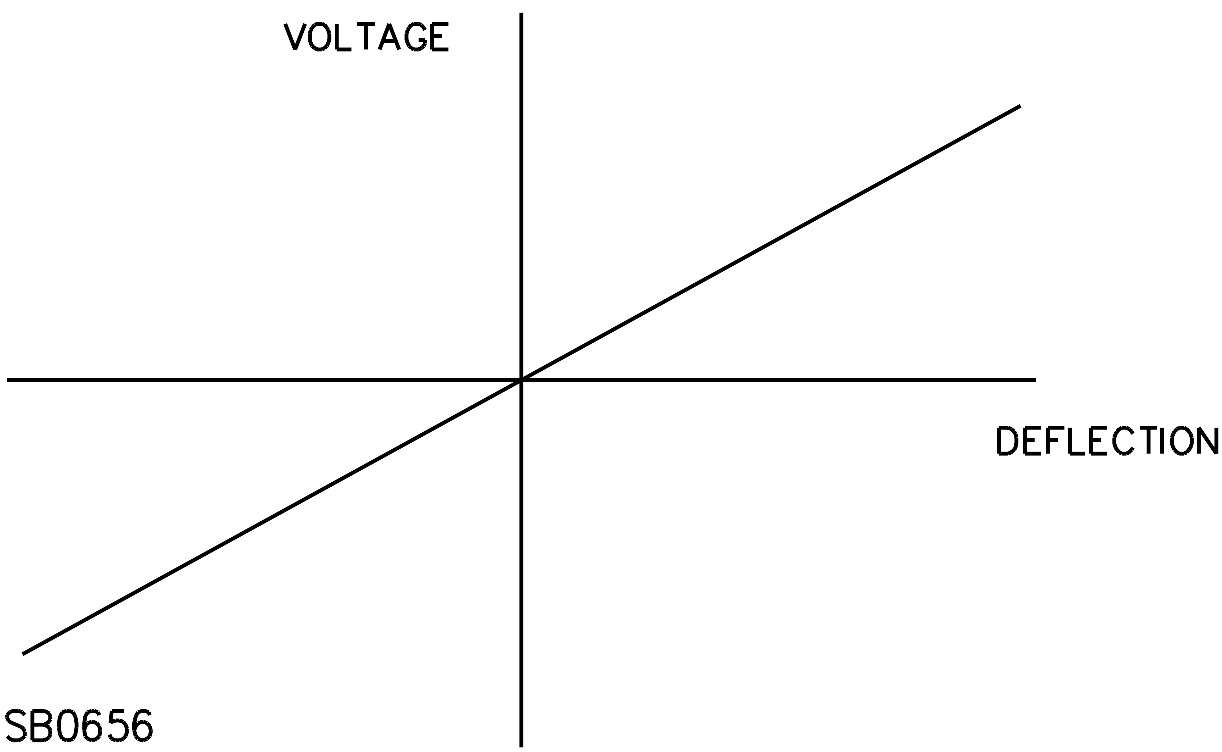
Measurements	Flat (± 5 percent) frequency response (Hz)
Voltage	50 – 3000
Current	50 – 1200 (for 100,000 A rms or less)
Current	50 – 3000 (for more than 100,000 A rms)

If the graph from a magnetic oscillograph does not enable accurate measurement a cathode ray oscilloscope shall be used as a referee.

Prior to any of the tests, the galvanometers shall be calibrated as follows:

a) using a variable DC voltage, deflection shall be plotted against applied voltage as shown in Figure A1;

Figure A1 – Deflection versus applied voltage



b) using an audio-oscillator having output impedance and output voltage necessary for driving a magnetic oscillograph galvanometer and capable of delivering at least 100 mA rms with a waveform that remains sinusoidal over a frequency range from 50 to 3000 Hz, the frequency of the signal applied to the galvanometer shall be gradually increased and it shall be determined that the peak-to-peak amplitude of the galvanometer deflection does not increase or decrease by more than 5 percent from the deflection at 60 Hz throughout this frequency range when corrected output voltage is supplied to the galvanometer and the sensitivity is adjusted to produce a deflection of not less than 25 mm (1 in);

c) using a battery capable of providing at least 12 V dc (under both open circuit and galvanometer load conditions), and a series resistance, the current through the galvanometer shall be adjusted to produce a deflection of at least 25 mm (1 in) under steady state conditions. A switching device having low-resistance, non-bounce contacts, such as those of a mercury relay, shall be connected in the galvanometer circuit;

d) while driving the oscillograph film at a speed of at least 2.29 m/s (90 in/s), the mercury-relay contacts shall be closed so as to cause a positive deflection of the oscillograph trace. After holding the contacts closed for at least 10 ms, they shall be re-opened for at least 10 ms. The trace shall return to zero;

e) with the polarity of the battery voltage reversed so as to cause a negative deflection of the oscillograph trace, the test in Item (d) shall be repeated. An equal deflection shall be obtained in this direction; and

f) during these tests, the transient deflection of the galvanometer upon energizing and de-energizing the relay shall produce some transient overshoot of the galvanometer.

Galvanometers may not track perfectly. To determine the amount of the tracking error, the galvanometers to be used during tests shall be connected in series while conducting the calibration tests. The difference in displacement between the various traces shall be applied as a correction factor during the actual tests.

During tests, galvanometers shall be used only within that portion of their range for which the trace is linear within ± 2 percent.

The sensitivity of the galvanometer and the rate of film travel should be sufficient to provide a record from which values of voltage, current, and power factor can be measured accurately.

The total impedance across the fuse in the measuring circuit shall not be less than 7000 ohms at 3000 Hz.

A2 Circuit calibration

With the test circuit of Figure 1 adjusted to provide the values of voltage and current specified in Clauses A2(a) and A2(b), a non-inductive (coaxial) shunt that has been found suitable for use as a reference shall be connected into the circuit as shown on the circuit diagram. The tests specified in Clauses A2(a) and A2(b) shall be conducted to verify the accuracy of the test facility's instrumentation and to determine that the power source and associated equipment are adequate for testing high interrupting rated fuses.

a) The test circuit shall be adjusted to provide the open circuit secondary voltage required for the test and short circuit current in rms symmetrical amperes equal to the interrupting rating of the fuse to be tested. With the secondary open-circuited, the transformer shall be energized and the voltage at the test terminals shall be observed to see if rectification is taking place. If rectification is occurring (see Figure A2), the circuit shall not be considered acceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings shall be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, this check can be omitted, provided that testing is not commenced before any distortion of the transformer open-circuit secondary voltage has disappeared.

b) With the test circuit adjusted as specified in Clause A2(a), but with the test terminals short-circuited with a bar of copper of negligible impedance, the circuit shall be closed as nearly as possible at the angle that will produce a zero offset of the current wave. The short circuit current in the secondary and the voltage on the primary shall be recorded. Using the test facility's and the referee instrumentation systems simultaneously, a comparison of measurements of secondary current (rms symmetrical current) shall agree within 10 percent of the lower value. The value of the power factor shall be indicated as less than 20 percent by both systems. Figure A3 is typical of oscillograms obtained when an AC circuit is closed as nearly as possible for zero offset of the current wave. Because of variation is the operation of the closing switch, closing time may not be exact and a slight amount of offset may occur.

In testing of fuses to determine acceptability of interrupting ratings, the reference non-inductive shunt and accompanying instrumentations shall be removed from the circuit.

Figure A2 – Rectified voltage wave (resulting from residual flux in transformer core)

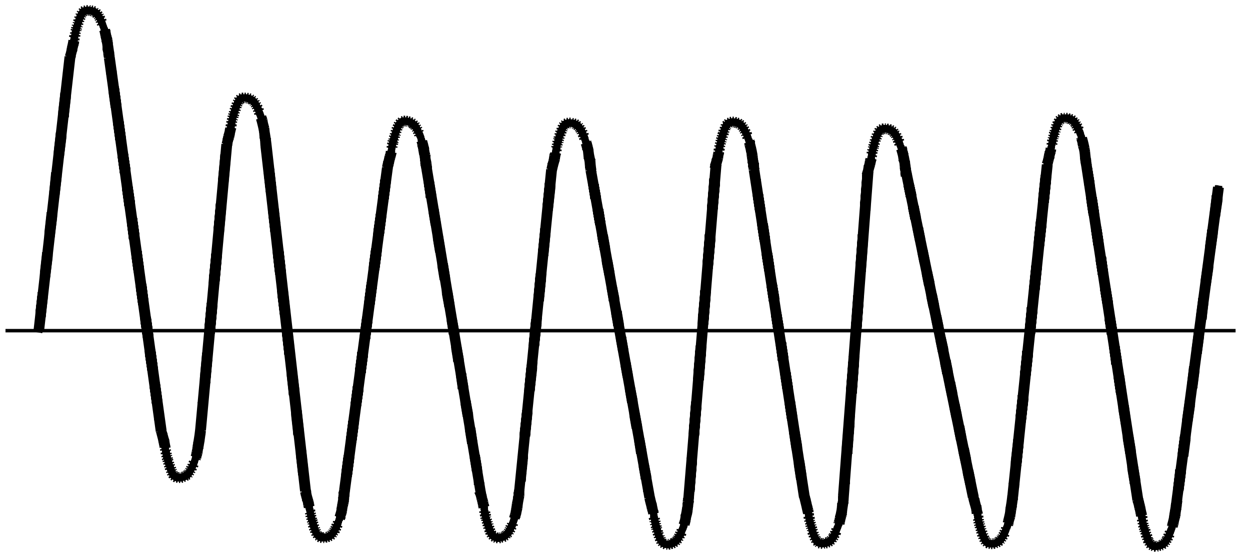


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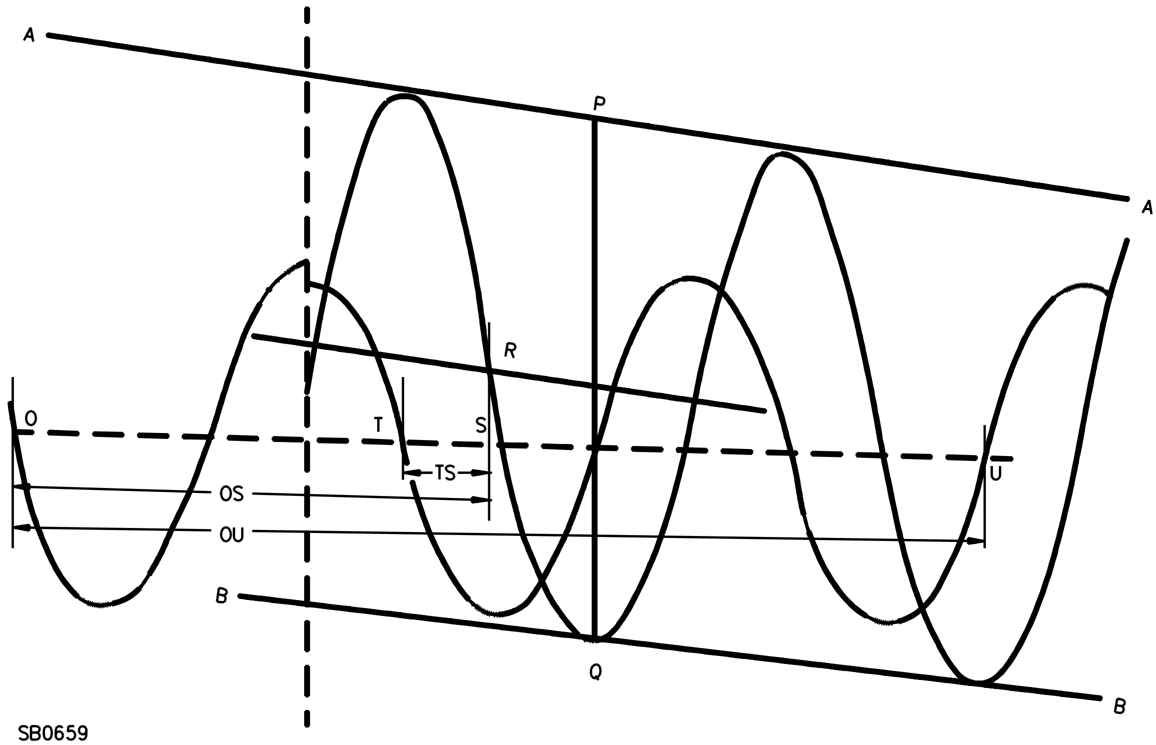
Figure A3 – Determination of power factor and available current

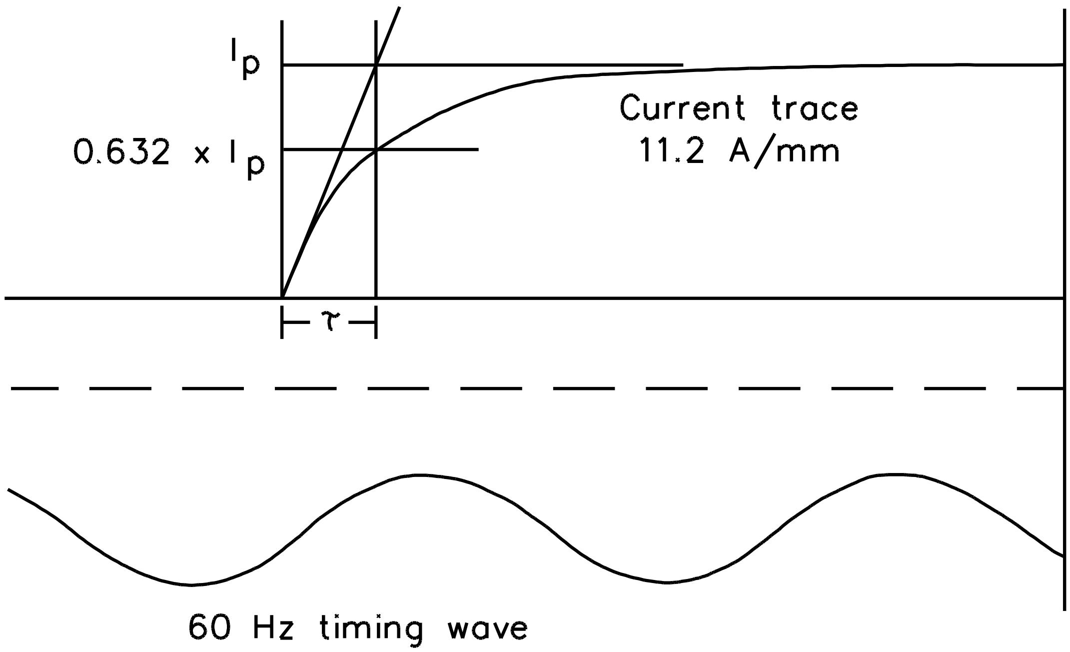


A3 DC circuit calibration example

Three quantities are important in calibrating a DC circuit – the voltage, the prospective current, and the time constant. The prospective current is simply the eventual maximum current measured at the midpoint of any ripple. The time constant gives an indication of the inductance of the circuit.

Figure A4 shows a sample oscillogram for a DC circuit calibration. The traces are current through the fuse and a timing wave.

Figure A4 – Sample oscillogram for DC circuit calibration



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The time constant, τ, is the time from circuit closure until the current reaches 0.632 times I_p.

I_p deflection = 31 mm

I_p = 31 mm x 11.2 A/mm ≈ 347 A (rounded)

0.632 x I_p deflection ≈ 19.6mm

From the timing wave the horizontal speed of the oscillogram is calculated:

Oscillogram speed(measured) = 65mm/cy

τ = 13 mm (measured) ÷ (60 cy/s x 65 mm/cy) = 3.33 ms

Appendix B

Instrumentation for interrupting rating tests

B1 Power factor determination

To determine the power factor from an oscillogram such as shown in Figure A3, a line AA connecting the first and third major peaks of the current wave shall be drawn. Through the second major peak, a line BB parallel to AA shall be drawn. Line PQ is perpendicular to the base line. P and Q are the points of intersection of the perpendicular with AA and BB respectively, and are within the first half cycle after initiation of current flow.

Through the midpoint of PQ a line shall be drawn parallel to AA and BB and extended so that it intersects the current wave at R. A perpendicular from R to the base line (zero deflection) intersects the base line at S.

If the oscillogram shows no appreciable variation in writing speed with respect to time, the distance OS, in electrical degrees, in Figure A3 represents the angle of displacement between the current and voltage waves plus 360°. The point 0 is where the open circuit voltage wave crosses the horizontal axis between 180° and 360° before switch closure. A variation in length of adjacent cycles or distance between adjacent time lines on an oscillographic record of more than 1.9 mm per 30 mm (1/16 in per in) is considered to be appreciable.

If the oscillogram shows appreciable constant unidirectional change in writing speed with respect to time, and if change of generator speed has not seriously distorted the voltage trace, the distance TS shall be used to represent the angle of displacement. In this case the time base used shall be the average determined over the distance from point 0 to point U which is 2-1/2 cycles later.

If the oscillogram shows appreciable variations of writing speed with respect to time and this variation is not essentially constant and unidirectional, or if it possesses these features but change in generator speed has seriously distorted the voltage trace, the oscillogram shall be considered unacceptable for measurement.

To determine the power factor from an oscillogram, such as shown in Figure B1, obtained from a closing achieving maximum asymmetry on a circuit having a power factor of not more than 20 percent, an envelope shall be drawn about the sinusoidal current wave. A perpendicular to the time axis shall be drawn 1/2 cycle after initiation of the current. Using the length of A and B as shown in Figure B1, the power factor shall be determined as indicated in item (a) or (b):

a)

$$Power\ Factor = \cos\left(\arctan\left(\frac{\pi}{\ln\frac{A+B}{A-B}}\right)\right)$$

b) Using the ratio M_m the power factor shall be determined from Table B1, where the ratio

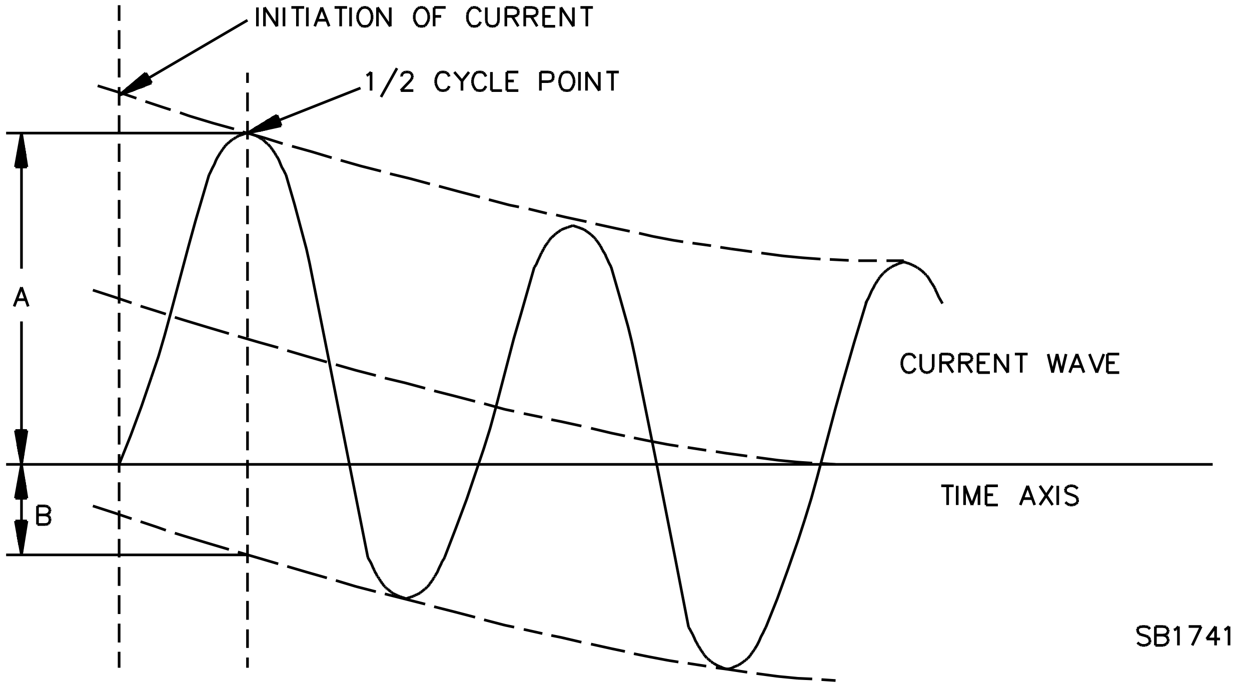
$$M_M = \frac{\text{asymmetrical rms amperes}}{\text{symmetrical rms amperes}} = \frac{\sqrt{(A + B)^2 + 2(A - B)^2}}{(A + B)}$$

If it can be shown for a given circuit that the same results are obtained as with the method described, other methods of determining power factor may be employed.

Table B1 – Short circuit power factor

Short circuit power factor (percent)	Ratio M_m
0	1.732
1	1.697
2	1.662
3	1.630
4	1.599
5	1.569
6	1.540
7	1.512
8	1.486
9	1.461
10	1.437
11	1.413
12	1.391
13	1.370
14	1.350
15	1.331
16	1.312
17	1.295
18	1.278
19	1.262
20	1.247

Figure B1 – Determination of power factor and available current



B2 Available current

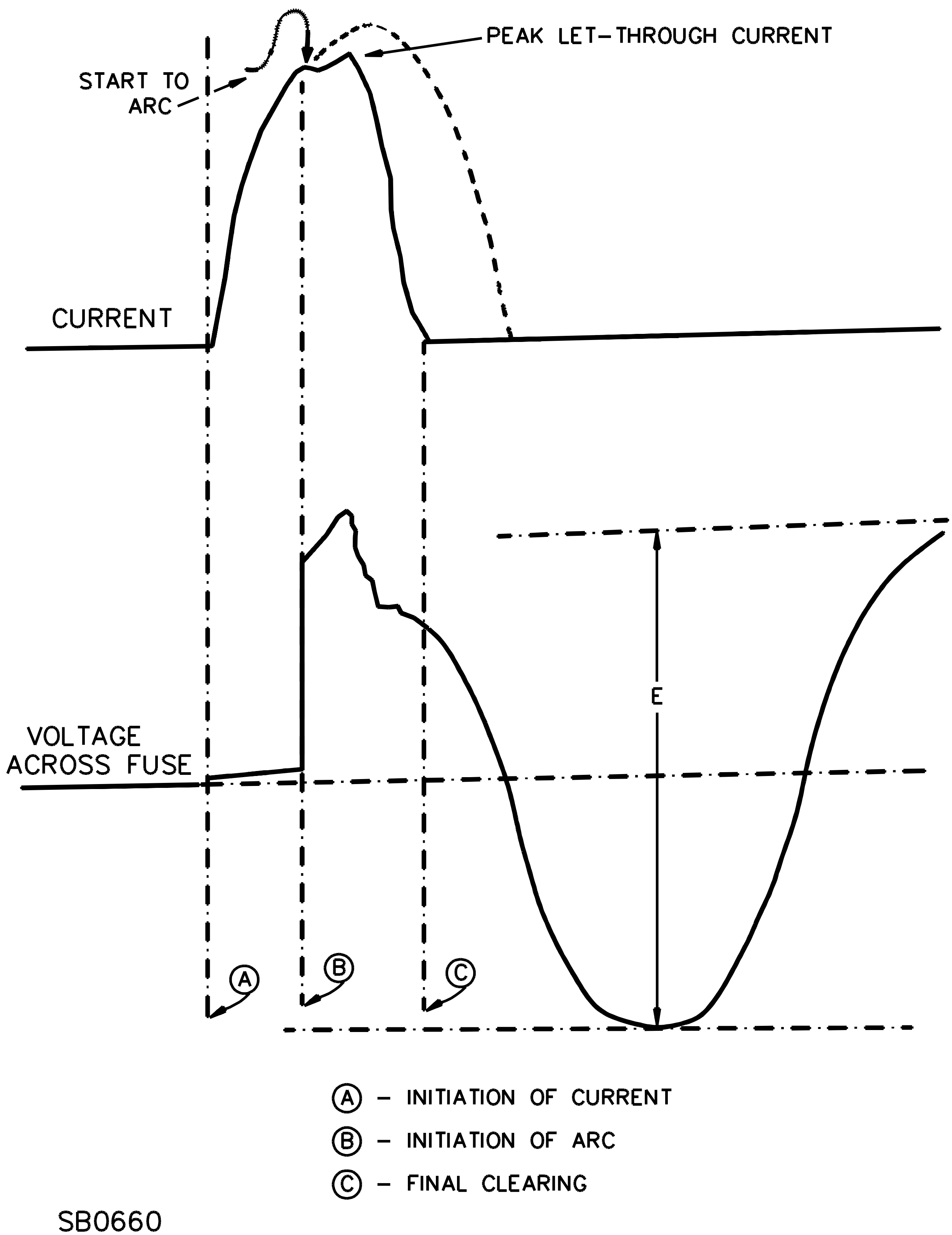
In Figure A3, PQ times a calibration factor equals I_a (available rms current) x 2√2. This value is determined in the first cycle after closure.

In Figure B1 (A + B) times a calibration factor equals I_a (available rms current) x 2√2. This value is determined 1/2 cycle after closure.

B3 Peak let-through current

Figure B2 is typical of an oscillogram obtained during the test of a fuse on an AC circuit and shows that this circuit was opened before the current could reach its first major peak.

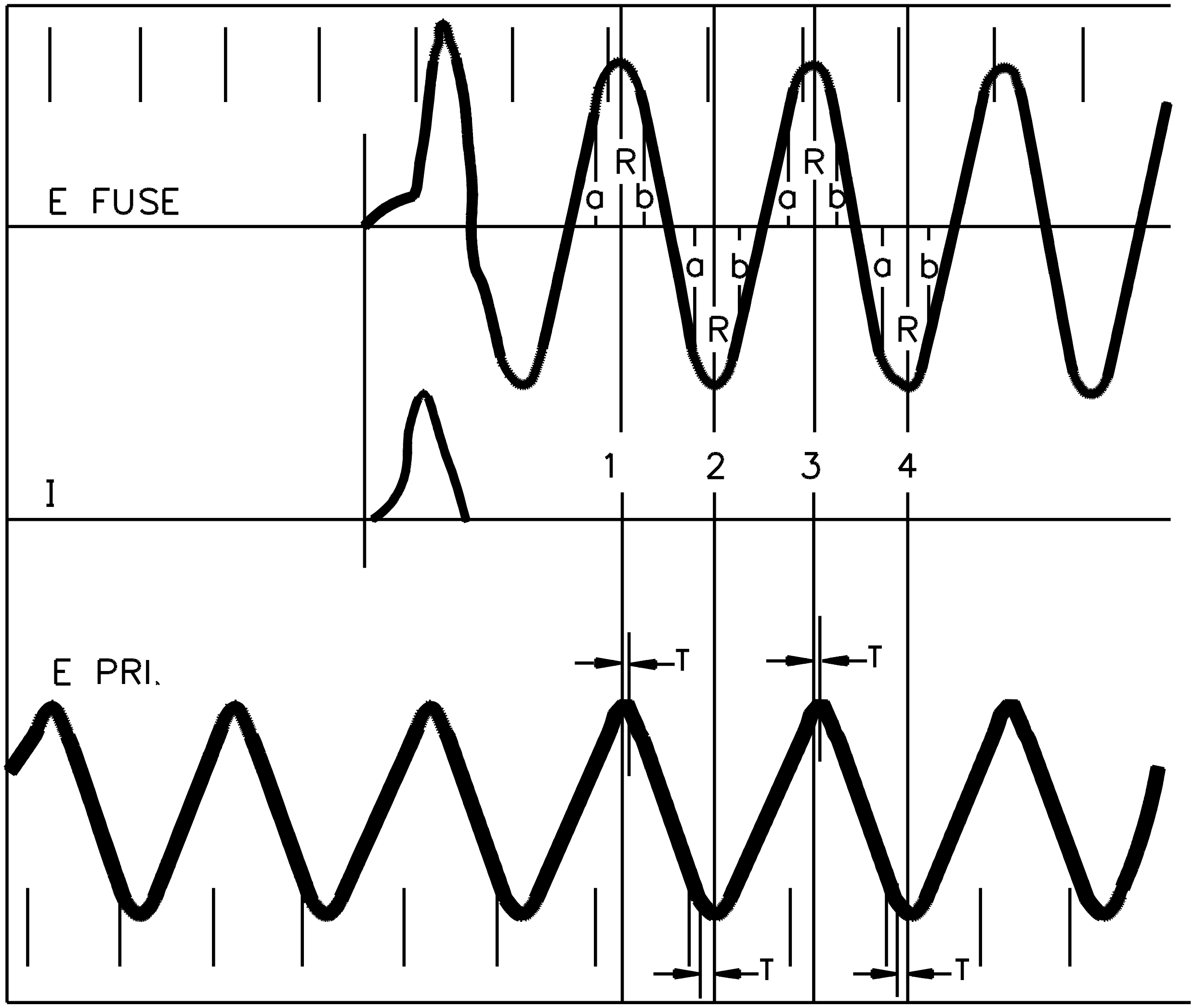
Figure B2 – Peak let-through current



B4 Recovery voltage

Figure B3 is typical of oscillograms obtained during the test of a fuse on an AC circuit and shows the voltage across the fuse prior to melting, during arcing, and after the fuse has operated to clear the circuit.

Figure B3 – Recovery voltage



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Note:

E = rms value of fuse rating

R ≥ √***2E***

T < 10°

a and b ≥ ***.75E***

((a + b) / 2) ≥ ***.85E***

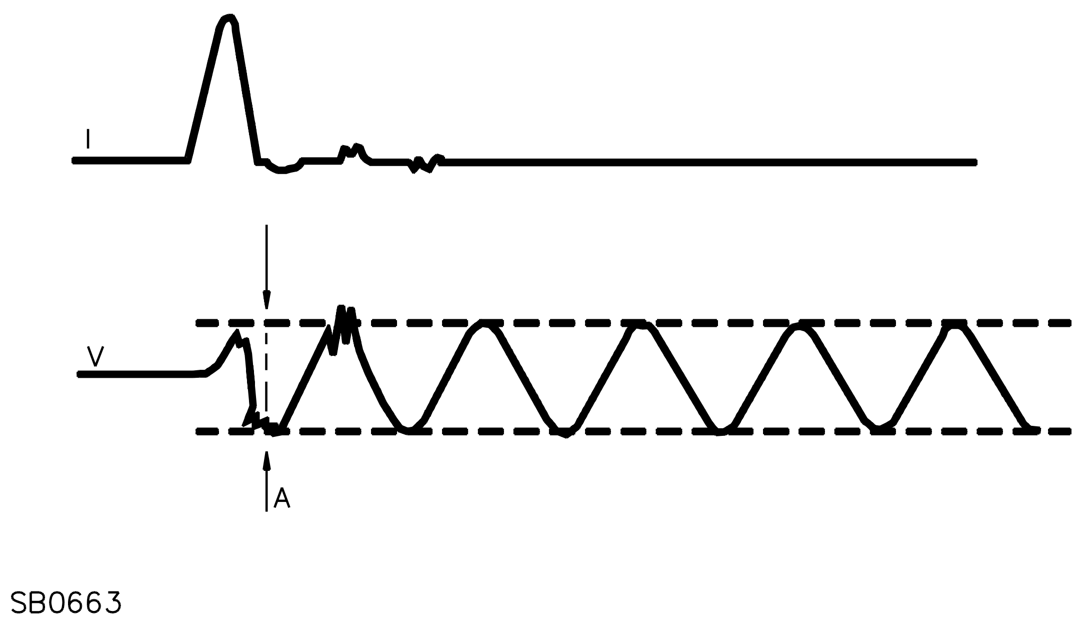
The peak value of the recovery voltage within the first full half cycle after clearing and for the next 3 successive peaks shall be at least equal to √2 times the rms value of the rated voltage of the fuse. Each of the peaks shall be displaced by not more than ±10 electrical degrees from the peak values of the open circuit secondary voltage. The average of the instantaneous value of the recovery voltage of each of the first 4 half cycles measured at the 45° and 135° points on the wave shall not be less than 85 percent of the rms value of the rated voltage of the fuse. The instantaneous value of the recovery voltage measured at the 45° and 135° points of each of the first 4 half cycles shall not be in any case less than 75 percent of the rms value of the rated voltage of the fuse.

If, in a circuit that employs secondary closing, there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave– when compared with the open circuit secondary voltage wave before current flows – the detailed measurement of recovery voltage characteristics shall not be required.

If peak voltage restrikes interfere with measurement of recovery voltage, the peak recovery voltage shall be determined by construction of envelope lines through the peaks of all unaffected peak voltage points on an oscillographic record showing at least 5 cycles, or more if necessary to obtain an acceptable number of undistorted peaks, following the initiation of the short circuit. The amplitude of the envelope immediately following the point of initial current interruption shall be at least 2√2 times the rms voltage rating of the fuse. Determination of voltage at the 45° and 135° points shall be made unless restrike phenomena actually interfere. See Figure B4.

Comparison of the recovery voltage peaks with the normal open circuit secondary voltage peaks can be accomplished by reference to open circuit primary voltage before closure of the switch or during the recovery period.

Figure B4 – Restrike phenomena



A* ≥ 2√2 x *E

B5 Comparison of instrumentation

The circuit shall be adjusted to provide the rated rms open circuit voltage of the fuse and, with the test terminals short circuited, a symmetrical short circuit current equal to the interrupting rating of the fuse to be tested. The shorting bar across the test terminals shall be replaced with a fuse indicated in the last sentence of this paragraph and the circuit shall be energized as early as possible for zero offset. Values of peak let-through current and I^2t shall be measured by using the 2 shunts (that of the test facility and the reference shunt) and shall compare within 10 percent of the lower value. When the same fuse rating is used for more than one voltage rating, the test need not be repeated. For testing, fuses rated 30, 100, and 600 A shall be used.

B6 Determination of I^2t

The let-through I^2t during the interruption of the circuit by the fuse shall be determined from either an oscillogram showing a current trace or by other equivalent means.

If applicable, the time base (in degrees per unit linear measure) shall be determined by averaging the distance between zero-line crossover points of the voltage wave or a timing wave in which the fuse current trace is most nearly centered.

Clearing I^2t is a measure of the let-through energy of the fuse during the total opening time, with a single-phase rms symmetrical available current, at a frequency of 48 – 62 Hz, at rated voltage, and at a power factor of 20 percent or less. It is measured with an integrating circuit, with an oscillograph using a recording speed of at least 2.25 m/s (90 in/s) and peak current deflections of at least 25 mm (1 in), or by other equivalent means. When using the oscillographic technique, it is calculated according to the recommended method for calculating I^2t from oscillograms. For fuse ratings of 100 A or less, the maximum deflection from the zero line may not be less than 12.7 mm (1/2 in) and for fuse ratings of more than 100 A, approximately 25 mm. Any records smaller than the values given above may be considered acceptable if, when used to compute the I^2t, 3 individual computations (made independently by 3 people) agree within 10 percent of each other and if the computed values are at least 25 percent below the maximum values specified. A photographic enlargement of the oscillographic records may be employed to provide a trace large enough for accurate measurement.

If the performance of the fuse is such as to make data obtained from a magnetic oscillograph record questionable, a cathode ray oscilloscope or an integrating circuit may be necessary to verify the test results.

B7 Oscillogram example

Figure B5 shows a typical oscillogram from a fuse test. The traces are system voltage, current through the fuse, and voltage across the fuse. Figure B6 shows the same oscillogram with notations for calculating the start-to-arc point, I_p, and I^2t.

Figure B5 – Typical fuse test oscillogram

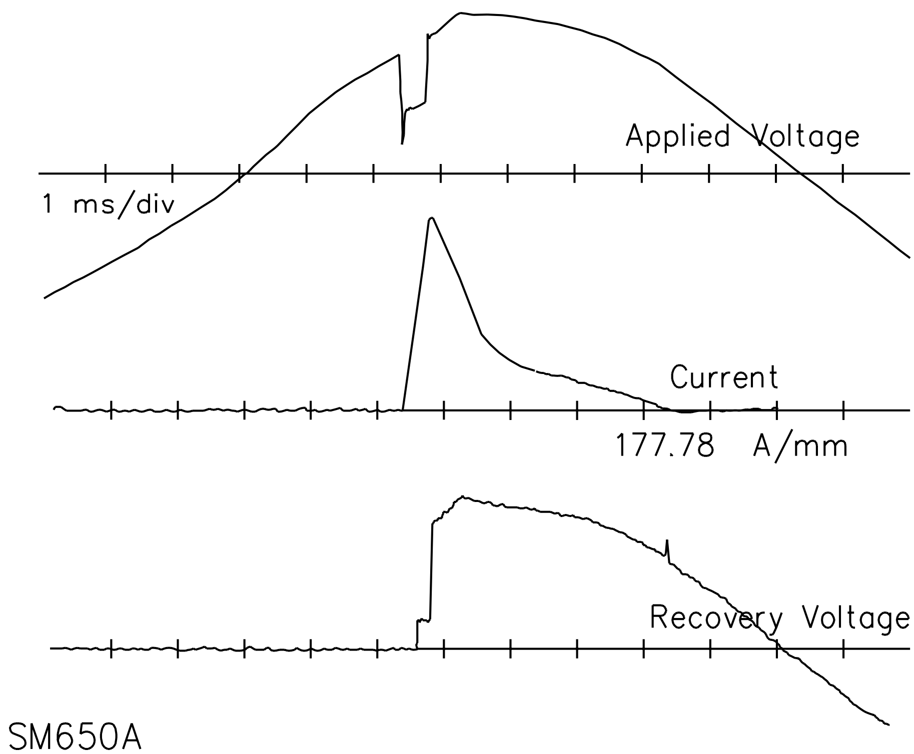
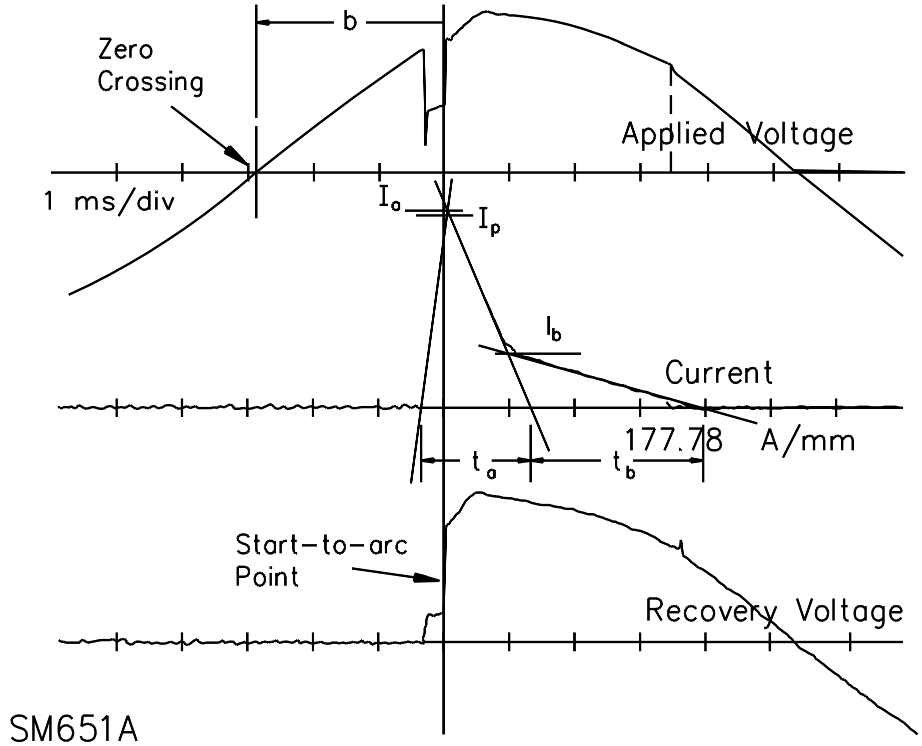


Figure B6 – Fuse test oscillogram with notations



The start-to-arc (STA) point can be seen where the voltage across the fuse begins to rise rapidly. Start-to-arc is measured in electrical degrees from the preceding zero crossing.

$$1\ div. = 1\ ms = 10.4\ mm\ (measured)$$

$$linear\ calibration = \frac{1}{(1000\ ms/s)\ x\ (10.4\ mm/ms)} = 0.000096\ s/mm$$

$$STA = b\ x\ linear\ calibration\ x\ 360^\circ/cycle\ x\ 60\ cycles/s$$

$$STA = 29\ mm(measured)\ x\ 0.000096\ s/mm\ x\ 360^\circ/cycle\ x\ 60\ cycles/s$$

$$STA = 60^\circ$$

To calculate the I_p, multiply the maximum vertical deflection by the current calibration. Care must be taken to include any other factors necessary to produce a current calibration in terms of peak amperes.

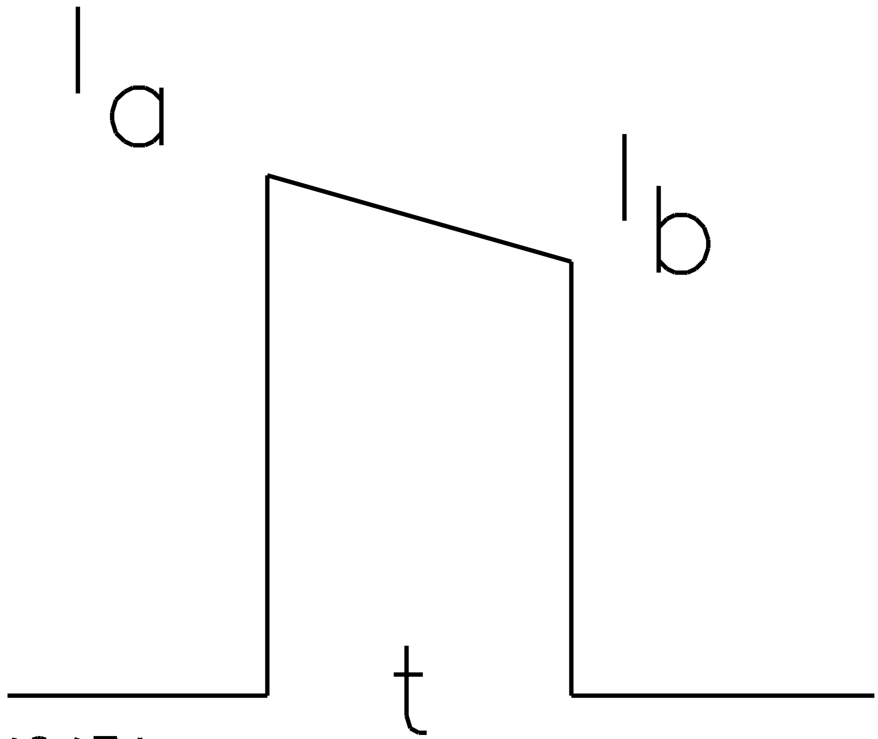
I_p = Deflection x current calibration

I_p = 30 mm x 177.78 A/mm

I_p = 5,330 amperes(rounded)

$$I^2t = \int_0^t I(T)^2\,dT$$

I^2t is the integral of the I^2 curve. In practice I^2t can be found by squaring the I curve and estimating the area under it. A reasonably accurate estimate can be made by filling the area under the current curve with triangles, rectangles, and/or trapezoids, and then summing the I^2t of each figure. Some useful formulas for this estimation are:



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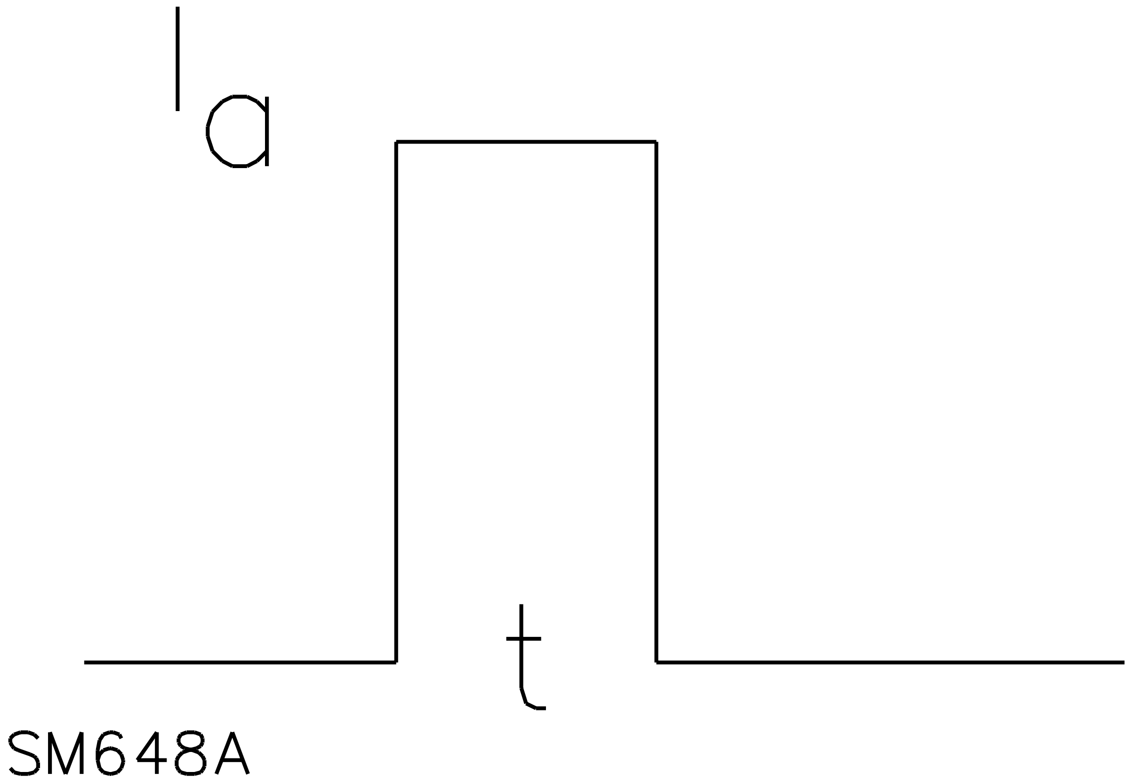
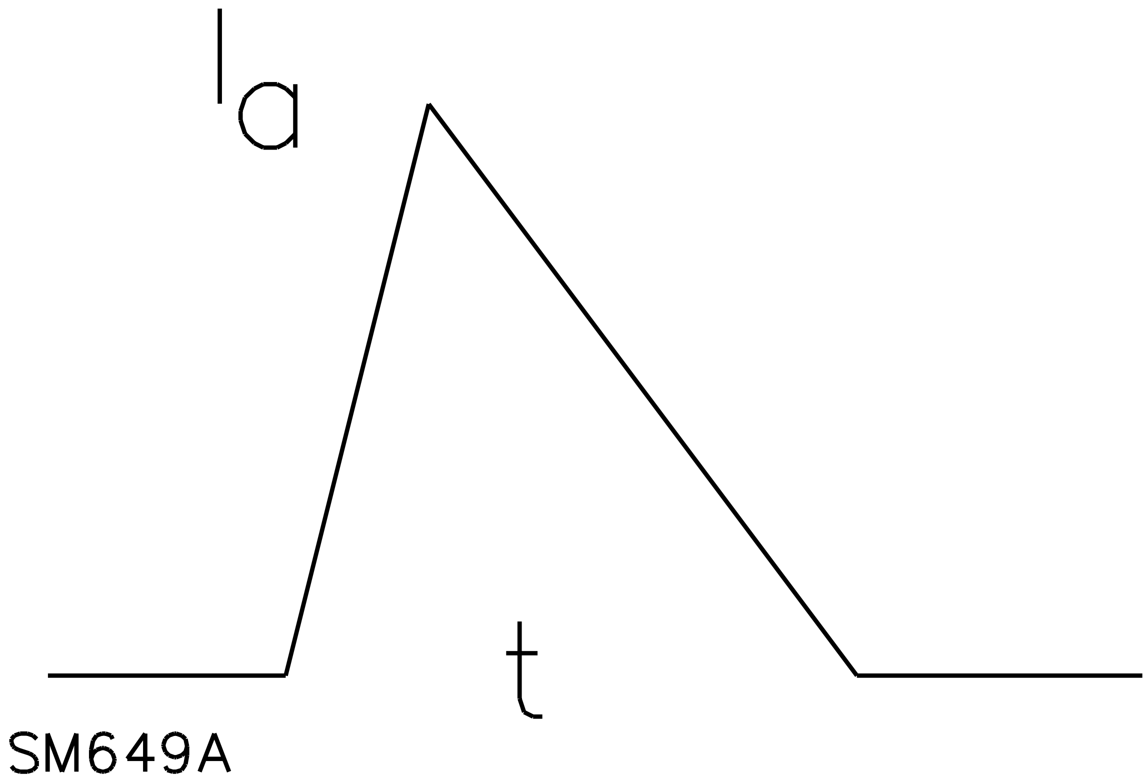
$$I^2t\ (Trapezoid) = \frac{1}{3}\left(I_a^2 + I_a I_b + I_b^2\right) t$$



$$I^2t\ (Rectangle) = I_a^2\, t$$



$$I^2t\ (Triangle) = \frac{1}{3}\ I_a^2 t$$

When using these figures for I^2t estimation, it is important to note the following:

a) I_a and I_b in the I^2t equations are not necessarily the same as I_p; and

b) because of the I^2 term in I^2t, the top portion of the current curve must be very carefully estimated.

In the example shown in Figure B6, the estimation uses two triangles to include the I curve. The larger triangle includes an area at the peak that will result in an overestimation of the I^2t. If this overestimation exceeds the limit for I^2t for this fuse, a more strict estimation (using 3 triangles and a rectangle for example) will be required. For the example:

$$I^2t = I_a^2 t_a + I_b^2 t_b$$

$$I_a^2 t_a = \frac{1}{3}(31\ mm \times 177.78\ A/mm)^2 \times 17\ mm \times 0.000096\ s/mm$$

$$I_b^2 t_b = \frac{1}{3}(8.5\ mm \times 177.78\ A/mm)^2 \times 27\ mm \times 0.000096\ s/mm$$

$$I^2t \approx 18{,}500\ A^2s\ (rounded)$$

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