UL 248-1

STANDARD FOR SAFETY

Low-Voltage Fuses – Part 1: General Requirements

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

Fourth Edition, Dated October 24, 2022

Summary of Topics

This new edition of ANSI/UL 248-1 dated October 24, 2022 is issued to incorporate editorial maintenance updates to the style, format, numbering, re-organization of content and to update references.

The requirements are substantially in accordance with Proposal(s) on this subject dated November 19, 2021.

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Low-Voltage Fuses – Part 1: General Requirements

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Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as "CSA Group"), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

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This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Fourth Edition. The most recent designation of ANSI/UL 248-1 as an American National Standard (ANSI) occurred on October 24, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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Preface

This is the harmonized ANCE, CSA Group, and UL standard for Low-Voltage Fuses – Part 1: General Requirements. It is the third edition of NMX-J-009/248/1-ANCE, the fourth edition of CSA C22.2 No. 248.1, and the fourth edition of UL 248-1. This edition of NMX-J-009-248/1-ANCE cancels the previous edition published in 2017. This edition of CSA C22.2 No. 248.1 supersedes the previous editions published in 1994, 2000, and 2011. This edition of UL 248-1 supersedes the previous edition published in 2017.

This harmonized standard was prepared by the Association of Standardization and Certification, (ANCE), CSA Group and Underwriters Laboratories Inc. (UL).

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

The present Mexican Standard was developed by the CT 32 from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of the fuse manufacturers and users.

This standard was reviewed by the CSA Subcommittee on Fuses and Fuseholders, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard has been developed in compliance with the Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity

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 standard is published as an identical standard for ANCE, CSA Group and UL.

An identical standard is a standard that is exactly the same in technical content except for national differences resulting from conflicts in codes and governmental regulations. Presentation is word for word except for editorial changes.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

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Low-Voltage Fuses – Part 1: General Requirements

1 Scope

1.1 This Standard applies to low-voltage fuses rated 1000 V or less, AC and/or DC, with interrupting ratings up to 300 kA (200 kA for Mexico). These fuses are intended to be used in accordance with the Canadian Electrical Code, Part I, CSA C22.1, NOM – 001, Mexican Electrical Code, and the National Electrical Code, NFPA 70.

1.2 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. The titles of the Clauses in this Part 1 correspond to the similarly titled Clauses in subsequent Parts.

2 Referenced Publications

2.1 Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

2.2 When a reference is made to a code or standard, the product shall comply with the code or standard of the country in which the product is intended to be used.

2.3 The following publications are referenced in this Standard:

United States	Canada	Mexico
NFPA 70, National Electrical Code	CSA C22.1, Canadian Electrical Code, Part I	NOM – 001, Mexican Electrical Code
	CSA C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II	

3 Units of Measurement

3.1 The values given in SI (metric) shall be normative. Any other values given shall be for information purposes only.

4 Definitions

4.1 Fuse

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

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

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

4.1.4 FILLER – Material used to fill a section or sections of a fuse.

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

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

4.2 General terms

4.2.1 AMBIENT AIR TEMPERATURE – The temperature of the air surrounding the fuse. Measurement of the ambient air temperature is conducted according to 11.1.3.

4.2.2 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.

4.2.3 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.

4.2.4 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.

4.2.5 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.

4.2.6 LOW MELTING POINT FUSE – A fuse that will open in an ambient air temperature of 200 °C when carrying 10 % of rated current.

4.2.7 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.

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

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

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

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

4.2.12 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.

4.3 Characteristic quantities

4.3.1 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.

4.3.2 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.

4.3.3 CONVENTIONAL FUSING CURRENT (I_f) – The lowest specified current which causes a fuse to open within a specified (conventional) time.

4.3.4 CONVENTIONAL NON-FUSING CURRENT (I_{nf}) – A specified current which a fuse is capable of carrying under specified conditions without opening.

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

4.3.6 CURRENT-LIMITING RANGE – The range of prospective currents from the threshold current to the interrupting current rating of a fuse.

4.3.7 CURRENT RATING (I_n) – The nominal rms AC or DC ampere rating, based on specified conditions, which is assigned to a fuse.

4.3.8 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.

4.3.9 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.

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

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

4.3.12 PEAK ARC VOLTAGE – The maximum instantaneous voltage across the fuse during the arcing time.

4.3.13 PEAK LET-THROUGH CURRENT (I_p) – The maximum instantaneous current through a fuse during interruption in its current-limiting range.

4.3.14 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.

4.3.15 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.

4.3.16 THRESHOLD CURRENT – The lowest prospective rms symmetrical current above which a fuse is current limiting.

4.3.17 THRESHOLD RATIO – The threshold current divided by the fuse current rating.

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

5 General

5.1 In Canada, general requirements applicable to this Standard are given in CSA C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II.

6 Service Conditions

6.1 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.

7 Classification

7.1 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, which covers most fuses included in this Standard and which identifies specific dimensions and short circuit performance characteristics, shall be used.

8 Characteristics

8.1 General

8.1.1 The following terms identify the characteristics of fuses covered by this Standard 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.

8.2 Voltage rating

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

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

8.3 Current rating

8.3.1 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.

8.4 Frequency rating

8.4.1 The AC frequency rating shall be 48 – 62 Hz.

8.5 Interrupting rating

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

8.5.2 The preferred DC interrupting ratings are 10,000, 20,000, 50,000, 100,000, 150,000, 200,000 or 300,000 A at the manufacturer's option.

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

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

9 Markings

9.1 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 those fuses which qualify according to the threshold test specified in 11.4, Test 3).

NOTE: Except for supplemental fuses, markings "D" and "P" are reserved exclusively for use with low melting point fuses.

9.2 Preferred symbols are as follows:

Unit of Measurement	Preferred Symbol
volts	V
amperes	A
kiloamperes	kA
milliamperes	mA

interrupting rating	IR or I_1
alternating current	∿ (IEC 60417 No. 5032)
direct current	⎓ (IEC 60417 No. 5031)
alternating & direct current	∿ (IEC 60417 No. 5033)
cycles per second	Hz
current limiting	

10 Construction

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

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

10.3 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.

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

10.5 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.

10.6 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.

10.7 Iron and steel parts shall be protected against corrosion.

11 Tests

11.1 General

11.1.1 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, 11.2;

b) Verification of overload operation, 11.3;

c) Verification of operation at rated voltage, 11.4; and

d) Verification of peak let-through current and clearing I^2t, 11.5.

11.1.2 The number of fuses to be tested is shown in Table 11.1.

NOTE: If the body material is other than indicated in 10.6, two sets of samples are used for rated voltage tests; one set is conditioned in accordance with footnote (e) and the other set in accordance with footnote (f), of Table 11.5.

11.1.3 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.

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

11.1.5 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.

11.1.6 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.

11.1.7 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 11.1
Number of Fuses to be Tested (may be modified by subsequent Parts)

Test	Current rating I_n, A		
	0 – 100	**101 – 600**	**601 – 6000**
Verification of temperature rise and I_{nf} (see 11.2)	3	3	1
Verification of overload operation (see 11.3)			
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	–
Verification of operation at rated voltage (see 11.4)			
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) 300 kA	1	1	1
h) maximum energy	1	1	1
i) threshold ratio	1	1	1
Verification of peak let-through current and clearing I^2t (see 11.5) shall be combined with the test in 11.4 above, items (d) – (g)	–	–	–

11.2 Verification of temperature rise and current-carrying capacity

11.2.1 General

11.2.1.1 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.

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

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

11.2.1.4 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.

11.2.1.5 The thermocouples shall consist of iron and constantan or chromel and alumel wires not larger than 24 AWG (0.21 mm^2).

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

11.2.2 Fuses rated 600 A or less

11.2.2.1 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.

11.2.2.2 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 11.2.

Table 11.2
Temperature Test Connections

Fuse current ratings I_n,	Minimum length[a]		Wire size	
A	m	(ft)	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.

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

11.2.2.4 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 two faces of the clamp making contact with the fuseholder terminals shall have an area greater than 323 mm^2 (1/2 in^2).

11.2.2.5 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.

11.2.2.6 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 four consecutive readings taken at 5 minutes intervals exceeds the average reading of these four 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.

11.2.3 Fuses rated 601 – 6000 A

11.2.3.1 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 11.3. 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 11.3
Bus Bar Cross Section and Shorting Bar Temperature Rises

Fuse current ratings I_n, A	Maximum bus bar cross section		Shorting bar temperature rise above room ambient, °C	
	cm^2	(in^2)	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

11.2.3.2 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 11.3.

11.2.3.3 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.

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

11.2.3.5 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.

11.2.3.6 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 four consecutive readings taken at 10 minute intervals exceeds the average reading of these four 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.

11.2.4 Acceptability of test results

11.2.4.1 As a result of testing:

a) No external soldered connections shall melt;

b) The fuse body or label may discolor but shall not char nor rupture in any manner and shall be readily identifiable for replacement purposes;

c) The temperature rise limits specified in the relevant subsequent Parts shall not be exceeded; and

d) Fuses shall not open during this test.

11.3 Verification of overload operation

11.3.1 The arrangement of the fuse and the test circuit shall be as specified in 11.2.

11.3.2 Fuses shall be tested singly. If a manufacturer so elects, fuses that performed acceptably in temperature rise or current carrying tests may be used for overload operation tests. The temperature of such fuses shall not be higher than that of the ambient air when the overload operation test is started.

11.3.3 The overload tests shall be conducted on a preset circuit or the current shall be adjusted to the required test current, within three seconds, at a uniform rate.

11.3.4 The time-delay test shall 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 shall then be replaced with the test fuse, the circuit turned on, and readjusted to the required test current, within three seconds, at a uniform rate.

11.3.5 As a result of testing:

a) The fuse shall operate according to the time limits specified in Table 11.4;

b) No external soldered connections shall melt; and

c) 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 11.4
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

Table 11.4 Continued on Next Page

Table 11.4 Continued

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
201 – 400	120	–	12	–	10
401 – 600	120	–	14	–	10
601 – 800	–	240	–	–	–
801 – 1200	–	240	–	–	–
1201 – 1600	–	240	–	–	–
1601 – 2000	–	240	–	–	–
2001 – 2500	–	240	–	–	–
2501 – 3000	–	240	–	–	–
3001 – 4000	–	240	–	–	–
4001 – 5000	–	240	–	–	–
5001 – 6000	–	240	–	–	–

11.4 Verification of operation at rated voltage

11.4.1 General

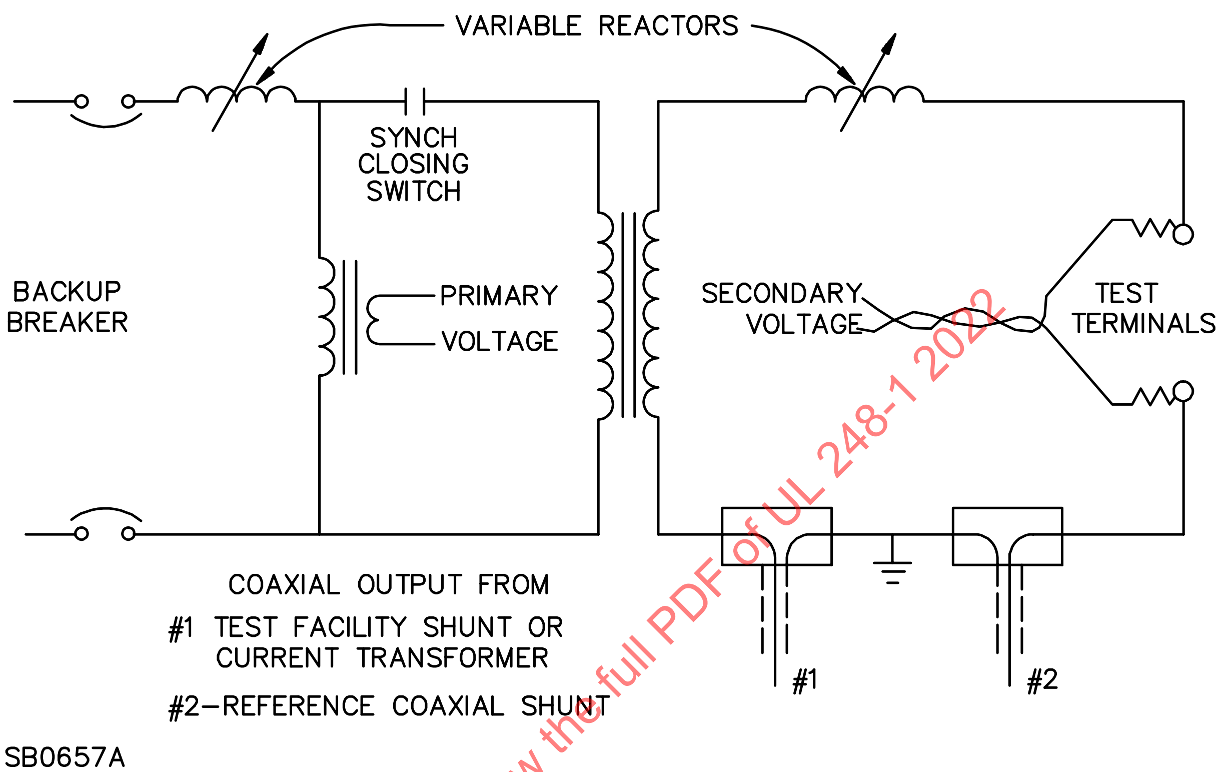
11.4.1.1 The fuse shall be mounted as in normal use, in a fuseholder for which it is intended, or in a test rig. The fuse may be mounted in a vertical or horizontal position. Before commencing tests, the specified external dimensions of the fuse shall be measured and recorded [see 11.4.4.1(d)].

11.4.1.2 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.

11.4.1.3 The test circuit shall be single phase, having the characteristics specified in Table 11.5. The test circuit is shown by way of example in Figure 11.1. 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.

Figure 11.1

Typical Test Circuit



11.4.1.4 The test circuit shall be calibrated as specified in Annex A.

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

11.4.1.6 To verify performance, one fuse at a time shall be tested in accordance with Table 11.5 for AC and Table 11.6 for DC. If the available current for any test is greater than the interrupting rating, then the test shall be waived.

11.4.1.7 For the low current tests 5a, 5b, and 5c of Table 11.5 and Table 11.6:

a) The fuse may be pre-heated by means of a reduced voltage circuit. This current shall be within ±20 % 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 second).

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

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

11.4.2 For AC circuits

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

11.4.2.2 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.

11.4.2.3 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 11.5.

11.4.2.4 For tests 1, 4a, 4b (see Table 11.5), the closing angle of the test circuit shall be between 0° and 90° on the voltage wave. For test 3, the closing angle shall be between 80° and 90°, with reference to the voltage wave.

Table 11.5
Verification of Operation at Rated Voltage for AC

<table>
<tr><th>Test</th><th>High current</th><th>Maximum energy</th><th>Threshold ratio</th><th colspan="3">Intermediate current</th><th colspan="2">Low current</th></tr>
<tr><td>Test No.</td><td>1</td><td>2</td><td>3</td><td>4a</td><td>4b</td><td>4c</td><td>5a</td><td>5b</td></tr>
<tr><td>Current</td><td>200 kA or 300 kA[g], if applicable</td><td>a</td><td>b</td><td>100 kA</td><td>50 kA</td><td>10 kA</td><td>3 I_n</td><td>2 I_n</td></tr>
<tr><td>Tolerance</td><td>+10 %
-0 %</td><td colspan="2">Not applicable</td><td colspan="3">+10 % -0 %</td><td colspan="2">+20 % -0 %</td></tr>
<tr><td>Power factor</td><td colspan="5">0.2 max.</td><td>0.45 to 0.5</td><td colspan="2">0.8 max.</td></tr>
<tr><td>Arcing angle[c]</td><td colspan="2">60° – 90°</td><td>Not specified</td><td colspan="2">60° – 90°</td><td colspan="3" rowspan="2">Random closing – No oscillographic records required</td></tr>
<tr><td>Closing angle</td><td colspan="2">Not specified</td><td>80° – 90°</td><td colspan="2">Not specified</td></tr>
<tr><td>Recovery voltage[d]</td><td colspan="6">Rated voltage +5 %, -0 %</td><td colspan="2">Rated +20 % voltage -0 %</td></tr>
<tr><td>Duration of recovery voltage</td><td colspan="2">30 s minimum</td><td>Not specified</td><td colspan="3">30 s minimum</td><td colspan="2">60 s minimum</td></tr>
<tr><td>Maximum arc voltage</td><td colspan="8">3000 V</td></tr>
<tr><td>Pre-conditioned</td><td>e
Yes</td><td>f
Yes</td><td>e
Optional</td><td colspan="2">e
Yes</td><td>No</td><td colspan="2">e
Optional</td></tr>
</table>

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

For maximum energy tests, the available current shall be adjusted such that the peak current at interruption is 70 – 100 % of the peak value of the rms current. This test is 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 % with the manufacturer's agreement.

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

NOTE: 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 shall be tested within 1 hour of removal from a humidity cabinet, after conditioning at room temperature 25 °C and 90 – 100 % relative humidity for 5 days.

[g] 300 kA if permitted in subsequent parts.

11.4.3 For DC tests

11.4.3.1 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.

11.4.3.2 Time constants shall be as specified in Table 11.6 or in the relevant subsequent Parts.

11.4.3.3 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 11.6 or the relevant subsequent Parts.

Table 11.6
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 % −0 %	Not Applicable	+20 % −0 %		
Time constant	≥10 ms	$\geq 0.5(I_{test})^{0.3}$ ms[b]			
Recovery voltage	Rated voltage +5 % −0 %		Rated voltage +20 % −0 %		
Duration of recovery voltage	30 s minimum	Not specified	60 s minimum		
Pre-conditioned	c Optional	d Yes	c Optional		

[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 shall be tested within 1 hour of removal from a 90 °C oven after at least 24 hours of conditioning.

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

11.4.4 Acceptability of test results

11.4.4.1 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 seconds 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.

11.4.4.2 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 shall 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 result of this test is considered non-conforming.

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

11.5.1 The fuse peak let-through current and clearing I^2t shall be evaluated from the results obtained from verification of operation at rated voltage, 11.4, when tested on circuits having available currents above the threshold currents.

11.5.2 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 Annex B for the methods to be employed.

11.5.3 As a result of testing, the peak let-through current and clearing I^2t shall be within the limits specified in the relevant subsequent Parts.

ANNEX A (Normative) – CIRCUIT CALIBRATION FOR INTERRUPTING RATING TESTS

A1 Galvanometers

A1.1 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 %) 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)

A1.2 If the graph from a magnetic oscillograph does not enable accurate measurement, a cathode ray oscilloscope shall be used as a referee.

A1.3 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 A1.1;

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 % 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;

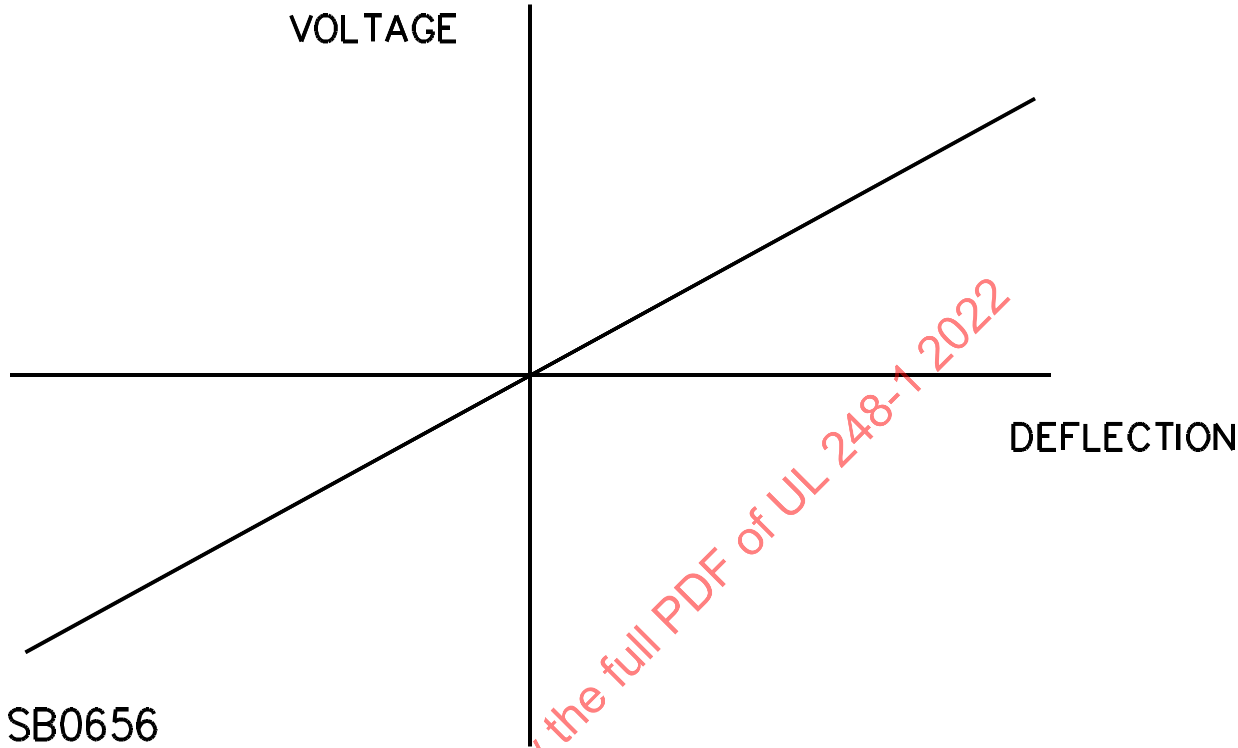
d) While driving the oscillograph film at a speed of at least 2.29 m/s (90 in/s), the mercury-relay contacts shall be closed so as to cause a positive deflection of the oscillograph trace. After holding the contacts closed for at least 10 ms, they shall be re-opened for at least 10 ms. The trace shall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

Figure A1.1

Deflection Versus Applied Voltage



A1.4 Galvanometers might 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.

A1.5 During tests, galvanometers shall be used only within that portion of their range for which the trace is linear within ±2 %.

A1.6 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.

A1.7 The total impedance across the fuse in the measuring circuit shall not be less than 7000 ohms at 3000 Hz.

A2 Circuit Calibration

A2.1 With the test circuit of Figure 11.1 adjusted to provide the values of voltage and current specified in (a) and (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 (a) and (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 A2.1), 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 may 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 (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 % of the lower value. The value of the power factor shall be indicated as less than 20 % by both systems. Figure A2.2 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 might not be exact and a slight amount of offset may occur.

A2.2 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 A2.1

Rectified Voltage Wave (resulting from residual flux in transformer core)

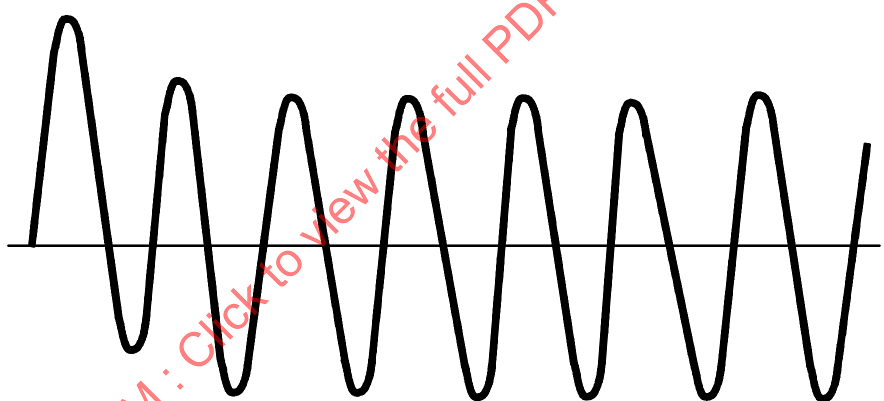


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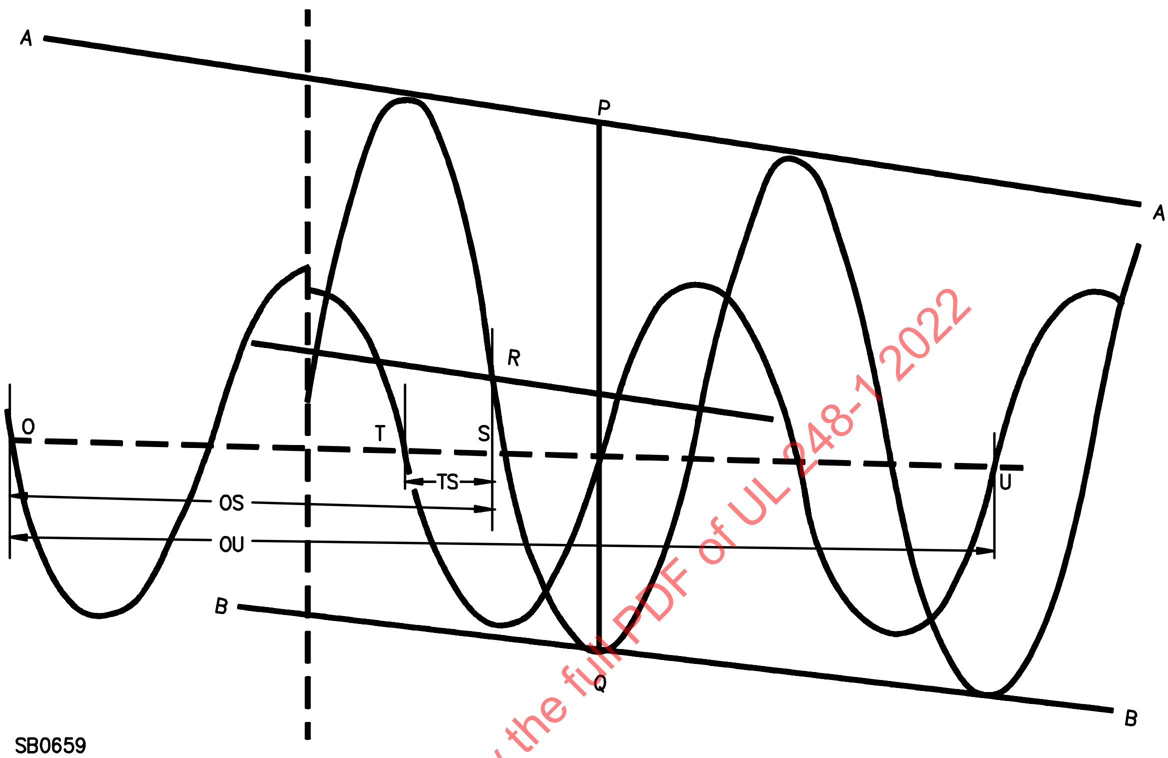
Figure A2.2

Determination of Power Factor and Available Current



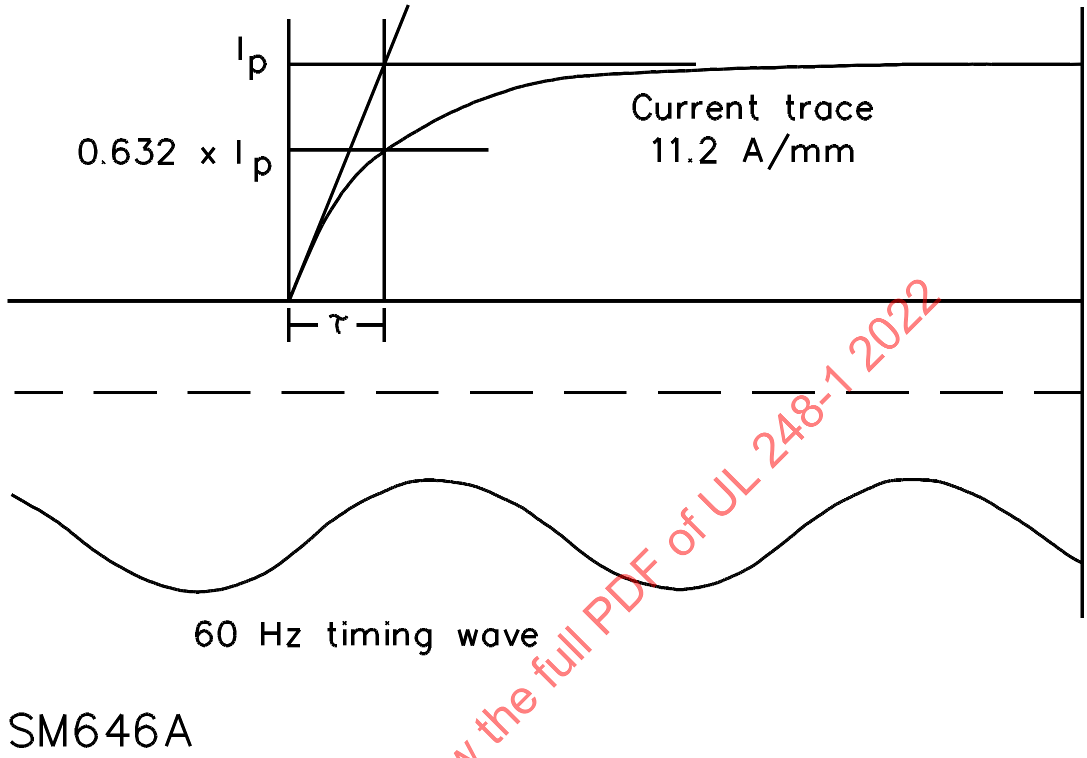
A3 DC Circuit Calibration Example

A3.1 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.

A3.2 Figure A3.1 shows a sample oscillogram for a DC circuit calibration. The traces are current through the fuse and a timing wave.

Figure A3.1

Sample Oscillogram for DC Circuit Calibration



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

$$I_p \; deflection = 31 \; mm$$

$$I_p = 31 \; mm \times 11.2 \; A/mm \approx 347 \; A \; (rounded)$$

$$0.632 \times I_p \; deflection \approx 19.6 \; mm$$

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

$$Oscillogram \;\; speed (measured) = 65 \, mm/cy$$

$$\tau = 13 \; mm \; (measured) \div (60 \; cy/s \times 65 \, mm/cy) = 3.33 \; ms$$

ANNEX B (Normative) – INSTRUMENTATION FOR INTERRUPTING RATING TESTS

B1 Power Factor Determination

B1.1 To determine the power factor from an oscillogram such as shown in Figure A2.2, 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.

B1.2 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.

B1.3 If the oscillogram shows no appreciable variation in writing speed with respect to time, the distance OS, in electrical degrees, in Figure A2.2 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.

B1.4 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.

B1.5 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.

B1.6 To determine the power factor from an oscillogram, such as shown in Figure B1.1, obtained from a closing achieving maximum asymmetry on a circuit having a power factor of not more than 20 %, 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 B1.1, the power factor shall be determined as indicated in (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 B1.1, where the ratio

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

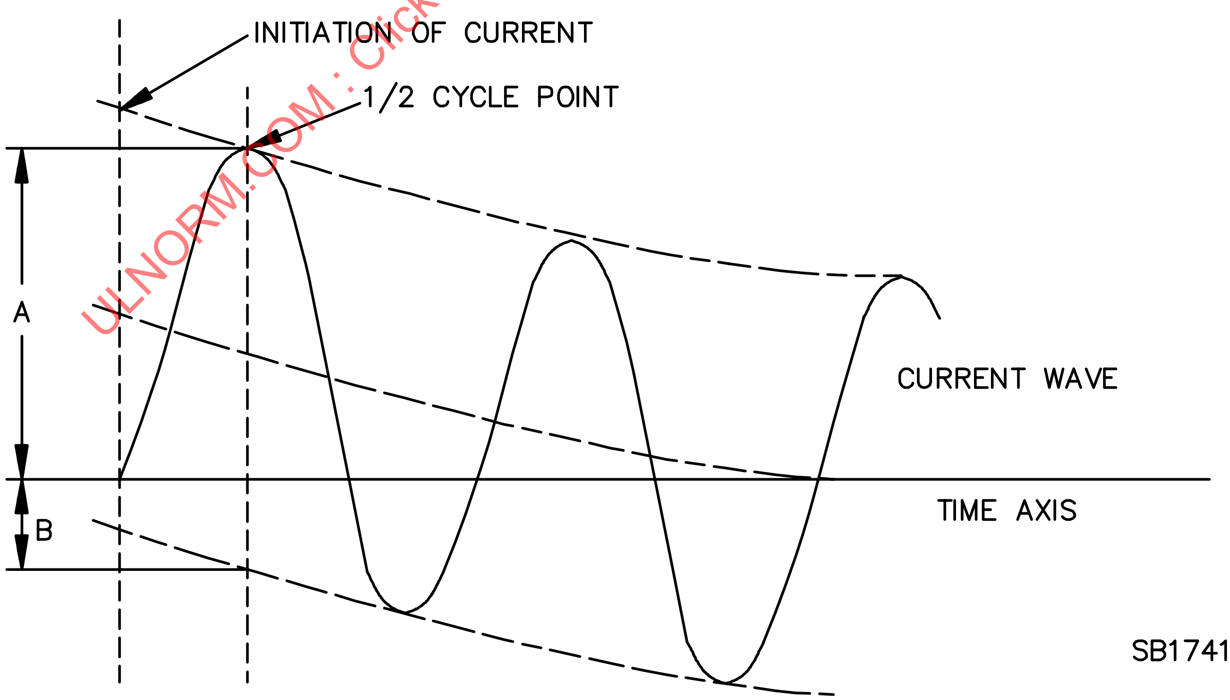
B1.7 If it can be shown for a given circuit that the same results are obtained as with the method described, other methods of determining power factor may be employed.

Table B1.1
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 B1.1

Determination of Power Factor and Available Current



B2 Available Current

B2.1 In Figure A2.2, PQ times a calibration factor equals I_a (available rms current) $\times 2\sqrt{2}$. This value is determined in the first cycle after closure.

B2.2 In Figure B1.1, (A + B) times a calibration factor equals I_a (available rms current) $\times 2\sqrt{2}$. This value is determined 1/2 cycle after closure.

B3 Peak Let-Through Current

B3.1 Figure B3.1 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.