



IEEE Standard Design Tests for High-Voltage (>1000 V) Fuses, Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Fuse Links and Accessories Used with These Devices

IEEE Power & Energy Society

Sponsored by the
Switchgear Committee

IEEE
3 Park Avenue
New York, NY 10016-5997, USA
13 March 2009

IEEE Std C37.41™-2008
(Revision of
IEEE Std C37.41-2000)

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**Switchgear Committee
of the
IEEE Power & Energy Society**

Approved 10 November 2008

IEEE-SA Standards Board

Abstract: Required procedures for performing design tests for high-voltage distribution class and power class fuses, as well as for fuse disconnecting switches and enclosed single-pole air switches, are specified. These design tests, as appropriate to a particular device, include the following test types: dielectric, interrupting, load-break, radio-influence, short-time current, temperature-rise, time-current, manual-operation, thermal-cycle, bolt-torque, and liquid-tightness.

Keywords: distribution enclosed single-pole air switches, fuse accessories, fuse design tests, fuse disconnecting switches, fuse enclosure package, high-voltage fuses

The Institute of Electrical and Electronics Engineers, Inc.
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PDF: ISBN 978-0-7381-5844-0 STD95852
Print: ISBN 978-0-7381-5845-7 STDPD95852

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Introduction

This introduction is not part of IEEE Std C37.41-2008, IEEE Standard for Design Tests for High-Voltage (>1000 V) Fuses, Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Fuse Links and Accessories Used with These Devices.

IEEE Std C37.41-2008 is a revision of IEEE Std C37.41-2000, done in order to bring it up to date and into agreement with current requirements for high-voltage fuses and switches. Distribution class oil cutouts were devices formerly covered by IEEE/ANSI standards. However, ANSI C37.44-1981, which covered specifications for such devices, has been withdrawn. Since these devices are now considered obsolete, testing for oil cutouts has been removed from this standard. The rules covering homogeneous series testing of expulsion fuses have been greatly expanded, and homogeneous series testing for parallel current-limiting fuses has been introduced. Certain information, previously in ANSI C37.53.1, concerning the testing of motor-starter fuses has been incorporated. Several changes to current-limiting fuse testing have been made to align more closely with the latest IEC test requirements. At the request of testing authorities, several clarifications concerning test methods and interpretation of results have been added. The Revision of Fuse Standards Working Group of the IEEE Subcommittee on High-Voltage Fuses prepared the standard. Liaison was maintained with the International Electrotechnical Commission (IEC) during the development of the revisions in order to incorporate the latest activities at the time of publication.

The Switchgear Committee of the IEEE Power and Energy Society has recently approved and published IEEE Std C37.100.1TM-2007 [B4].^a Although IEEE Std C37.100.1-2007 is not specifically referenced in this document, any information that may apply to fuse devices has been incorporated.

This standard is one of a series of complementary standards covering various types of high-voltage fuses and switches, arranged so that certain standards apply to all devices while other standards provide additional specifications for a particular device. For any device, IEEE Std C37.40TM, this IEEE Std C37.41TM, plus any additional standards covering that device, constitute a complete standard for the device. In addition, IEEE Std C37.48TM provides application, operation, and maintenance guidance for all the devices, and it is supplemented by IEEE Std C37.48.1TM-2002 [B3], which is an operation, classification, application, and coordination guide for current-limiting fuses.

At the time this standard was approved, this series was comprised of the following standards:

ANSI C37.42, American National Standard Specifications for High Voltage Expulsion Type Distribution Class Fuses, Cutouts, Fuse Disconnecting Switches and Fuse Links.

ANSI C37.46, American National Standard for High Voltage Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnecting Switches.

ANSI C37.47, American National Standard for High-Voltage Current-Limiting Type Distribution Class Fuses and Fuse Disconnecting Switches.

IEEE Std C37.40TM, IEEE Standard Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.

IEEE Std C37.41TM, IEEE Standard Design Tests for High-Voltage (>1000 V) Fuses, Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Fuse Links and Accessories Used with These Devices.

^aThe numbers in brackets correspond to those of the bibliography in Annex F.

IEEE Std C37.43™, IEEE Standard for Specifications for High-Voltage Expulsion, Current-Limiting and Combination Type Distribution and Power Class External Fuses, With Rated Voltages from 1kV through 38kV, Used for the Protection of Shunt Capacitors.

IEEE Std C37.45™, IEEE Standard Specifications for High-Voltage Distribution Class Enclosed Single-Pole Air Switches with Rated Voltages from 1 kV through 8.3 kV.

IEEE Std C37.48™, IEEE Guide for Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.

IEEE Std C37.48.1™, IEEE Guide for the Operation, Classification, Application, and Coordination of Current-Limiting Fuses with Rated Voltages 1–38 kV.

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1. Overview

1.1 Scope

This standard specifies design test requirements for high-voltage (above 1000 V) fuses, distribution enclosed single-pole air switches, disconnecting cutouts, fuse disconnecting switches, and accessories for use on ac power and distribution systems. Devices with rated maximum voltages to 170 kV are covered. The devices to which this standard applies are as follows:

- a) Distribution and power class expulsion type fuses
- b) Distribution and power class current-limiting type fuses
- c) Distribution and power class fuse disconnecting switches
- d) Item a) through item c) used in fuse enclosure packages
- e) Fuse supports of the type intended for use with distribution and power class fuses, and fuse disconnecting switches
- f) Fuse and disconnecting cutouts
- g) Disconnecting devices created by the use of a removable switch blade in a distribution or power class fuse support
- h) Distribution class enclosed single-pole air switches

- i) Distribution class and power class expulsion, current-limiting, and combination types of external capacitor fuses used with a capacitor unit, groups of units, or capacitor banks
- j) Backup current-limiting fuses (“motor-starter fuses”) used in conjunction with high-voltage Class E2 motor starters (see ANSI/UL 347-2000 [B1])¹
- k) Fuse links when used exclusively with distribution class and power class fuses, and distribution class and power class fuse disconnecting switches
- l) Item a) through item d) and item f) through item i) having integral load-break means

1.2 Purpose

This standard specifies the minimum testing requirements for fuses and related devices. Such standardization is needed to ensure uniform minimum product testing for devices within the document scope. Test areas covered are based on historical experience.

1.3 Background

The distribution and power class expulsion type fuses listed in 1.1 are similar to those now covered in IEC 60282-2.² The distribution class expulsion type fuses are similar to the class “A” fuses covered in the document, and the power class fuses are similar to their class “B” fuses. Some of the current-limiting type fuses listed in 1.1 are similar to those now covered in IEC 60282-1. However, significant differences exist in the testing requirements of IEC and IEEE/ANSI. IEEE fuse standards primarily reflect applications common in North America and in countries that use electrical systems designed using similar principles. IEC standards tend to rely heavily on practices common in Europe. Since IEC testing differences include testing at different voltages for the same fuse rated voltage, and different or no testing for fuses intended for use in a surrounding temperature above 40 °C, the user is advised to exercise extreme caution if devices specified and tested per IEC standards are compared with those specified and tested per IEEE/ANSI standards. The differences in test requirements may result in devices tested to IEC not being suitable for applications where devices tested to IEEE/ANSI standards are required, or vice versa.

In the headings and the text of this document, there are some areas where information is included in brackets []. The information in the brackets is a term used in IEC standards that may be similar to the term used in this document, a term that is common in some parts of the world, or a term that has been used previously in IEEE or ANSI standards. Caution is again advised when making comparisons.

1.4 Description of fuse-enclosure packages (FEPs) using expulsion type indoor power class fuses

- *Type 1E*: A fuse mounted in an enclosure with relatively free air circulation within the enclosure (e.g., an expulsion fuse mounted in an enclosure or vault).
- *Type 2E*: A fuse mounted in a container with restricted air flow surrounding the fuse, but with relatively free air circulation within the enclosure on the outside of the container (e.g., an expulsion fuse in an enclosure with insulating barriers that form a container that restricts the air flow).
- *Type 3E*: A fuse directly immersed in liquid and mounted in an enclosure with relatively free liquid circulating around the fuse (e.g., an expulsion fuse in a liquid-filled switchgear enclosure).

¹ The numbers in brackets correspond to those of the bibliography in Annex F.

² Information on references can be found in Clause 2.

1.5 Description of FEPs using current-limiting type indoor distribution and power class fuses

- *Type 1CL*: A fuse mounted in a large enclosure with relatively free air circulation within the enclosure (e.g., a fuse mounted in a live-front pad-mounted transformer or in a vault). The relevant fuse rated maximum application temperature (RMAT) is based on that of the air that is cooling the fuse. It may be noted that if a fuse were mounted outdoors but in an ambient temperature above 40 °C, conditions on the fuse would be the same.
- *Type 2CL*: A fuse mounted in a fuse container. This is a relatively small enclosure, defined as one supporting the fuse and restricting the air, gas, or liquid flow surrounding the fuse (e.g., a fuse inside a canister in a transformer or a vault). However, the fluid flow (gas, liquid, or a combination of the two) that cools the outside surface of the container has relatively free circulation. The relevant fuse RMAT is based on that of the fluid that is cooling the container. Fuses tested in accordance with 6.6 (i.e., tested for use in air no hotter than 40 °C), which are encapsulated with solid insulation (e.g., rubber or epoxy), can be considered to be this type of FEP when so encapsulated. In this case, the relevant fuse RMAT is based on that of the fluid that is cooling the encapsulated fuse.
- *Type 3CL*: A fuse directly immersed in liquid and mounted in an enclosure with relatively free liquid circulation around the fuse (e.g., an oil-immersed fuse in a transformer or switchgear enclosure). The relevant RMAT is based on that of the liquid that is cooling the fuse.

NOTE—In IEEE Std C37.41™-2000 and the versions of ANSI C37.46, ANSI C37.47, and IEEE Std C37.48™ approved before this standard, FEPs using current-limiting fuses are designated as being of types 1C through 5C. In order to simplify FEP types, include additional types, and align with IEC practice, these types have been rationalized into three categories. Type 2CL includes the former types 2C, 3C, and 4C, whereas type 3CL is the same as type 5C. The new classifications will be introduced into the other standards when they are revised.³

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so that each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C37.42, American National Standard Specifications for High Voltage Expulsion Type Distribution Class Fuses, Cutouts, Fuse Disconnecting Switches and Fuse Links.⁴

ANSI C37.46, American National Standard for High Voltage Expulsion and Current-Limiting Type Distribution Class Fuses and Fuse Disconnecting Switches.

ANSI C37.47, American National Standard for High Voltage Current-Limiting Type Distribution Class Fuses and Fuse Disconnecting Switches.

ANSI C63.2-1987, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 1 GHz—Specifications.

IEC 60282-1, High Voltage Fuses—Part 1, Current-Limiting Fuses.⁵

³ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

⁴ ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

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IEC 60282-2, High Voltage Fuses—Part 2, Expulsion Fuses.

IEEE Std 4™-1995, IEEE Standard Techniques for High-Voltage Testing.^{6, 7}

IEEE Std C37.20.3™, IEEE Standard for Metal-Enclosed Interrupter Switchgear.

IEEE Std C37.40™, IEEE Standard Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.

IEEE Std C37.43™, IEEE Standard for Specifications for High-Voltage Expulsion, Current-Limiting and Combination Type Distribution and Power Class External Fuses, With Rated Voltages from 1kV through 38kV, Used for the Protection of Shunt Capacitors.

IEEE Std C37.45™, IEEE Standard Specifications for High-Voltage Distribution Class Enclosed Single-Pole Air Switches with Rated Voltages from 1 kV through 8.3 kV.

IEEE Std C37.48™, IEEE Guide for Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.

NOTE—Fuse standards listed as “ANSI C37.xx,” were formerly developed by NEMA. The responsibility for maintaining them has passed to the IEEE and will, at their next revision, carry the designation “IEEE Std C37.xx.”

3. Required tests

3.1 General

The tests to be conducted upon completion of a design or following a design change that affects performance are summarized in Table 1 and are completely specified in the appropriate standards listed below:

- ANSI C37.42
- IEEE Std C37.43
- IEEE Std C37.45
- ANSI C37.46
- ANSI C37.47

⁶ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

⁷ The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

Table 1—Design tests required

Design test given in following sections of this standard	ANSI C37.42			IEEE Std C37.43		IEEE Std C37.45	ANSI C37.46	ANSI C37.47
	Specifications for high-voltage expulsion type distribution class fuses, cutouts, fuse disconnecting switches, and fuse links			Specifications for high-voltage distribution and power class expulsion, current-limiting, and combination types of external capacitor fuses for shunt capacitors		Specifications for high-voltage distribution class enclosed single-pole air switches	Specifications for high-voltage expulsion and current-limiting type power class fuses and fuse disconnecting switches	Specifications for high-voltage current-limiting type distribution class fuses, and fuse disconnecting switches
	Fuse cutouts	Disconnecting cutouts	Fuse links	Capacitor line fuses	Capacitor unit fuses			
5. Dielectric ^a	X	X	—	X	—	X	X ^b	X ^b
6. Interrupting	X	—	X ^c	X	X	—	X ^b	X ^b
7. Load-break	X ^d	X ^d	—	X ^d	—	—	—	—
8. Radio-influence ^a	X	X	—	X	X	X	X ^b	X ^b
9. Short-time current	—	X	—	—	—	X	—	—
10. Temperature-rise	X	X	X	X	X	X	X ^b	X ^b
11. Time-current	—	—	X	X	X	—	X	X
12. Manual-operation, thermal-cycle, and bolt-torque	X	X	—	—	—	—	—	—
13. Liquid-tightness	—	—	—	—	—	—	X ^e	X ^e
14. Expendable-cap static-relief pressure	X ^f	—	—	X ^f	—	—	—	—

^a Required only on fuses and fuse units when they are mounted in a particular fuse support (see 5.1 and 8.1.1).

^b When these types of fuses are used in enclosures, additional tests may be required. See the appropriate IEEE/ANSI standard listed above for complete requirements.

^c Required only on open-link fuses.

^d Required only on load-break cutouts having means provided for breaking load current.

^e Required only on liquid-submersible fuses used in FEP.

^f Required only on expendable caps for expendable-cap cutouts.

3.2 Device tests

For devices covered by this standard, all applicable tests need not be performed on each design modification of a previously qualified design. To assure that overall performance has not been adversely affected as a result of the design modification, sufficient tests shall be performed to ensure that the modified design will have a performance that meets or exceeds the ratings and performance requirements of the standards specified in Clause 3. For devices that have been assigned ratings or performance requirements that are different from the standards specified in Clause 3, the modified design shall have ratings and performance requirements that meet or exceed the values assigned to the original device.

Fuses connected in parallel shall be considered a separate design and be tested accordingly. Note that this includes fuses mounted in parallel by the fuse manufacturer and those intended by the manufacturer to be paralleled by another party. When single current-limiting fuses have been tested in accordance with IEEE Std C37.41, the testing of these fuses in parallel is subject to the homogeneous testing rules in 6.6.4.

3.3 FEP tests

The design tests for FEPs are performed to determine the adequacy of a particular type of design, style, or model of equipment to meet its assigned ratings and for satisfactory operation. In general, a fuse need not be tested if it has already been tested in an equivalent enclosure.

3.4 Test values

3.4.1 Allowable tolerances

Testing parameters in this document and the specification documents for each device are listed as a value with an allowable plus tolerance (e.g., +5% –0%), a value with an allowable minus tolerance (e.g., +0% –10%), a minimum value, a maximum value, or a range. When a range is specified, the test may be performed anywhere within that range. When a minimum value or a value with a plus tolerance is specified, the manufacturer may perform the test at any value that equals or exceeds the minimum value (e.g., voltage). When a maximum value or a value with a minus tolerance is specified, the manufacturer may perform the test at any value that is equal to or less than the maximum value allowed. When a minimum value, maximum value, or a tolerance is specified, testing by persons other than the manufacturer shall be at the specified value, or permission to test at a different level shall be obtained from the manufacturer. The general principle to be followed is that a manufacturer, for testing convenience, may choose to test with values more severe than prescribed for the tests, whereas other persons performing tests shall obtain approval from the manufacturer before more severe testing is performed.

3.4.2 Preferred values

In this standard and the specification standards referred to herein, the ratings and performance requirements represent preferred values and requirements. Special circuit or environmental conditions may require devices with ratings and performance that are different from the preferred values and requirements specified in these documents. For these devices, the user and the manufacturer shall agree upon the ratings and performance requirements.

3.5 Testing responsibility

A fuse or switch manufacturer shall test their device and supply the appropriate application data. An FEP manufacturer is responsible for ensuring that appropriate testing has been performed and for supplying the appropriate application data.

3.6 Test report

The results of all tests shall be recorded in a test report containing the data necessary to prove compliance with the applicable standards. The test report shall include the manufacturers name and completely describe the device tested. Photographs of devices as tested, type numbers, production drawings, product bulletins, or other descriptive literature for the device may be included.

4. Common test requirements

4.1 General

The requirements of Clause 4 are common to all tests. Where the conditions for a specific test deviate from these common test requirements, they are identified in the specific subclause for the test.

4.2 Test site conditions

4.2.1 Ambient temperature during test

The ambient temperature prevailing at the test site shall conform to the usual service conditions in accordance with IEEE Std C37.40.

4.2.2 Atmospheric conditions during test

Tests shall be conducted under atmospheric conditions prevailing at the time and place of the test. It is recommended that the barometric pressure and dry and wet bulb thermometer readings be recorded so that applicable correction factors can be applied to the measurements.

4.3 Frequency and wave shape of test voltage

4.3.1 Frequency of test voltage

The frequency for all power-frequency tests shall be (50 ± 2) Hz or (60 ± 2) Hz, except as otherwise specified.

4.3.2 Wave shape of test voltage

A sine wave of acceptable commercial standards shall be applied to the device. For the definition of the wave shape, see IEEE Std 4-1995.

4.4 Devices to be tested

4.4.1 Condition of device to be tested

The device shall be new and in good condition, and tests shall be applied before the device is put into commercial service, unless otherwise specified.

4.4.2 Compatibility of components

Unless otherwise specified, tests performed according to this standard shall utilize components made by the same manufacturer or as recommended for use by the manufacturer.

4.5 Acceptance criteria

The successful completion of tests listed in this standard requires that various criteria be met, including the following:

- a) A device shall perform all of its intended functions. While it is not feasible to list all possible device functions, typical examples are that devices intended to drop down, drop open, or initiate operation of other devices after current interruption shall perform these functions in their intended manner on all interrupting test series (see NOTE 2).
- b) A filled current-limiting fuse shall not emit filler material or flame during interrupting tests, although a minor emission of flame from a striker or indicating device is permissible, provided this does not cause breakdown or significant leakage to ground.

- c) Fuses that operate an indicating device need not comply with any specific requirements but shall visually and fully operate. If a current-limiting fuse includes a device, the only function of which is to provide indication of a fuse operation, and that indicator does not operate, then although the fuse has failed to pass the test as a fuse with an indicator, the test may be used as part of a series to demonstrate that an otherwise identical nonindicating fuse has met the requirements of the standard.
- d) After an interruption test, all parts of the device shall be in proper position, and the fuse shall be removable from its support in one piece as intended.

In addition, after replacing parts that are normally field replaceable (see NOTE 1), excluding a fuse holder, the condition of the device shall be as follows:

- e) *Mechanical requirements:* In substantially the same condition as at the beginning of the test. Depending on the current interrupted during interrupting tests, it is acceptable for the bore of expulsion devices to have some amount of erosion.
- f) *Electrical requirements:* Capable of carrying rated current continuously at the rated maximum voltage. If there is evidence to suggest the device may not be able to carry rated current continuously because of contact deterioration, a temperature-rise test shall be performed using the maximum size fuse link, fuse unit, or refill unit. This temperature-rise test shall be performed on the device at rated current for the time it takes for the temperature to stabilize. Temperatures reached by the device may be higher than those achieved by a new device. The criterion for acceptability is long-term temperature stabilization.
- g) *Dielectric requirements:* If there is evidence of insulator contamination from the test, a power-frequency dry-withstand test shall be performed at 75% of the normal test value for the device.

After certain groups of tests, as specified in Table 7, Table 8, Table 11, and Table 19, the fuse holder may be changed. The acceptance criteria e) through g) are to be met with the fuseholder that has just been tested, even though it may not be suitable for any additional testing.

NOTE 1—Examples of parts that are normally field replaceable include replaceable fuse links, fuse units, refill units, expendable caps, and exhaust-control devices. Requirements of individual tests may limit the replacement of some parts until certain tests, or groups of tests, have been completed.

NOTE 2—The location of the lower test conductor relative to the fuseholder of a fuse or fuse cutout may, on some tests, influence its dropout characteristics by interfering with the movement of the fuse link leader (the flexible conductor used to complete the electrical circuit between the fusible element and the lower fuseholder contact). The manufacturer's recommendations for conductor placement relative to the tested device should therefore be followed.

4.6 Test-conductor dimensions

4.6.1 Interrupting, load-break, and short-time test conductors

Electrical connections shall be made by a bare conductor connected to each terminal of the device being tested. These conductors shall be of sufficient size to carry the test current adequately for the anticipated time. The source side lead shall be connected to the upper terminal of the device and the return or load side lead to the lower terminal, unless normal service conditions, manufacturer's recommendations, or other IEEE Std C37.41 clauses require that the connections be reversed or that the device be mounted horizontally. For general-purpose and full-range current-limiting fuses, test series 3 tests (long-time melting tests) shall use conductor sizes as specified in Table 2, unless the manufacturer specifies a different conductor size due to the typical application.

4.6.2 Dielectric and radio-influence test conductors

Electrical connections shall be made by a bare conductor connected to each terminal of the device being tested. These conductors shall be the smallest size the device terminal is designed to accept. Use of other wire sizes is acceptable if it can be demonstrated that this size does not affect the test results.

4.6.3 Temperature-rise and time-current test conductors

Electrical connections shall be made by a bare conductor connected to each terminal of the device being tested. These conductors shall be of the size and length specified in Table 2. For fuses connected in parallel, the current rating to be considered is the total current assigned by the manufacturer.

4.7 Mounting and grounding of the device for tests

4.7.1 General

Devices shall be mounted in the normal service position(s) recommended by the manufacturer. Where more than one service position exists, the orientation that results in the most onerous duty shall be used. When grounding of a particular part of the device is required during the test, the ground lead(s) shall be of a sufficient size so that it can adequately carry any anticipated current for the expected duration of current flow. If detection of the ground current is desired, then current-metering devices may be used. Specific mounting and grounding information for the various devices to be tested is described in 4.7.2 through 4.7.7.2.

Table 2—Size and length of bare conductor for specified tests

Rated continuous current of fuse cutout, switch, or fuse support (A)					Size and length of bare copper leads	
Distribution enclosed, open, and open-link cutouts when tested as a:		Distribution enclosed air switch	Power fuse and distribution current-limiting fuse	Size of leads	Minimum length	
Fuse cutout	Disconnecting cutout				m	(in)
50	—	—	Up to 50	No. 6 AWG Solid	1.2	(48)
—	100	—	—	No. 2 AWG Stranded	1.2	(48)
100	—	—	100	No. 1 AWG Stranded	1.2	(48)
—	200	—	—	No. 2/0 AWG Stranded	1.2	(48)
200	—	200	200	No. 4/0 AWG Stranded	1.2	(48)
—	300	300	300	250 kcmil	1.2	(48)
—	—	400	400	400 kcmil	1.2	(48)
—	—	600	—	600 kcmil	1.2	(48)

4.7.2 Distribution class expulsion type fuses, cutouts, and distribution class expulsion type fuse disconnecting switches

Crossarm-mounted, distribution class, expulsion type fuses, cutouts, and fuse disconnecting switches shall be mounted on a wood crossarm that measures 9 cm × 11 cm (3½ in × 4½ in) in cross section. The device mounting bracket shall be grounded by a lead attached to the mounting bracket on the side of the crossarm

opposite the device. Devices designed for other types of mounting arrangements shall be mounted in their normal service positions, and the mounting structures shall be grounded.

4.7.3 Distribution class enclosed single-pole air switches

Distribution class enclosed single-pole air switches shall be mounted on a wood crossarm that measures 9 cm × 11 cm (3½ in × 4½ in) in cross section. The mounting bracket shall be grounded by a lead attached to it on the side of the crossarm opposite the switch.

4.7.4 Power class expulsion fuses, power class current-limiting fuses, and power class fuse disconnecting switches

Power class expulsion fuses, power class current-limiting fuses, and power class fuse disconnecting switches, shall be mounted on a rigid structure. The base shall be grounded.

4.7.5 Distribution class current-limiting fuses and fuse disconnecting switches

Distribution class current-limiting fuses and fuse disconnecting switches shall be mounted on a rigid structure. The base shall be grounded.

4.7.6 Distribution and power class fuses and fuse disconnecting switches used in FEPs

Distribution fuses, power class fuses, and fuse disconnecting switches used in FEPs shall be mounted in accordance with the fuse manufacturer's specifications. The enclosure and base of the device, as applicable, shall be grounded.

4.7.7 Distribution and power class external fuses for shunt capacitors

4.7.7.1 Capacitor line fuses

Depending on the class and type of line capacitor fuse, it shall be mounted as specified in 4.7.2, 4.7.4, 4.7.5, or 4.7.6.

4.7.7.2 Capacitor unit fuses

For interrupting tests on expulsion and current-limiting capacitor unit fuses that automatically provide an isolating gap after operation, the fuses shall be mounted in the same manner as they would be used in a capacitor bank. An energized fuse shall be placed on each side of the fuse under test, in the normal service position, to determine that any expulsion gas or part movement does not reduce clearances or dielectric properties that might cause flashovers and, as such, cause operation of these adjacent fuses.

Current-limiting fuses not having a disconnect or isolating feature may be mounted in any convenient manner.

For temperature-rise tests, the mounting configuration shall simulate the capacitor bank configuration where the fuse is to be used and shall be such that it does not restrict or promote heat transfer in a manner different from service conditions.

5. Dielectric tests

5.1 General

Dielectric test procedures shall be as specified in Clause 4 and as described in Clause 5.

Dielectric tests are performed to determine the power-frequency dry and wet dielectric withstand voltages, and withstand voltages, from an energized part to adjacent energized or grounded parts. They are performed to test a device's dielectric properties from terminal to terminal (open gap) or from terminals to parts that may be grounded in service. This standard does not cover dielectric testing across a blown (or unblown) fuse of any type, or across a fuseholder without a fuse link installed, since no meaningful or useful data can be obtained with such tests.

Any test of this type must be performed on the fuse in its mounting. The test should be configured so that the electrical stress on the fuse and mounting, which is created by mechanical structures of the mount, the spatial relationship between other phases, and sources of voltage and grounds, match the electrical stress that the device under test will experience in use. The manufacturer of the device under test should detail any restrictions on the location of any adjacent structures or ground. Any test summary or report should detail the locations of these associated parts.

Dielectric tests for unit type capacitor fuses are dependent on the capacitor bank configuration and design and cannot be assigned to the fuse itself.

5.2 Measurement of test voltages

The voltage for dielectric tests shall be measured and corrected for standard conditions in accordance with IEEE Std 4-1995.

5.3 Description of power-frequency dry-withstand voltage tests

5.3.1 Application of test voltage

The test voltage specified, with appropriate atmospheric corrections, shall be applied to the device for 1 min.

Seventy-five percent of the rated dry-withstand voltage may be applied in one step and then gradually raised to the required value in not less than 5 s and not more than 30 s.

5.3.2 Acceptance criteria

There shall be no flashover or damage to the insulating material.

NOTE—The terminal-to-terminal (open gap) required dielectric withstand values for some devices are 10% higher than those from terminal to ground. However, successful completion of these gap tests does not ensure that a device, when open, will flashover to ground instead of across the open gap.

5.4 Description of power-frequency wet-withstand voltage tests on outdoor devices

5.4.1 Application of test voltage

The test voltage specified, with appropriate atmospheric corrections, shall be applied to the device per IEEE Std 4-1995. Corrections for relative humidity shall not be made on wet-withstand tests. Seventy-five percent of the rated wet-withstand voltage may be applied in one step and then gradually raised to the required value in not less than 5 s and not more than 30 s.

5.4.2 Application of test precipitation

Precipitation shall be applied per IEEE Std 4-1995. Due to long field experience, the conventional procedure, practice in the United States for precipitation conditions, is acceptable for devices tested according to this standard. If testing per this procedure, the water shall be projected downward toward the front of the device and at an angle of 45° from the vertical, so that the spray strikes equally on the front and on one sidewall of the device. The standard test procedure defined by IEEE Std 4-1995 is also fully acceptable for the purposes of meeting this standard, at the manufacturer's option.

5.4.3 Acceptance criteria

There shall be no flashover or damage to the insulating material.

5.5 Description of power-frequency dew-withstand voltage tests on indoor devices

5.5.1 Dew test procedure

The insulation of the device shall be thoroughly cleaned. The cleaned device shall be placed in a cold chamber (refrigerator) having a temperature of $-10\text{ }^{\circ}\text{C}$ to $-15\text{ }^{\circ}\text{C}$ until it is thoroughly cooled (may take 10 h to 12 h). The device shall then be mounted in a test chamber having a normal temperature of $22\text{ }^{\circ}\text{C}$ to $25\text{ }^{\circ}\text{C}$ and a humidity of approximately 100%. When the device is completely covered with dew, the test voltage as specified in 5.5.2 shall be immediately applied.

5.5.2 Application of test voltage

The test voltage specified, with appropriate atmospheric corrections, shall be applied to the device for 10 s. Corrections for relative humidity shall not be made on dew-withstand tests. Seventy-five percent of the rated dew-withstand voltage may be applied in one step and then gradually raised to the required value in not less than 5 s and not more than 30 s.

5.5.3 Acceptance criteria

There shall be no flashover or damage to the insulating material.

5.6 Description of impulse withstand voltage tests

5.6.1 Impulse test voltage wave shape

The wave shape and application of the $1.2/50\text{ }\mu\text{s}$ full-wave test voltage is described in IEEE Std 4-1995 and shall have the following limits for design tests.

The impulse test wave shall have a virtual front time less than or equal to 1.2 μs , a crest voltage greater than or equal to the rated full-wave impulse withstand voltage, and a time, from initiation, of at least 50 μs for the voltage to fall to 50% of the crest value.

It may be noted that in the event that laboratory limitations are encountered due to the capacitance of the test device, the maximum rise achievable may be used if it is mutually acceptable to the user and the manufacturer.

5.6.2 Polarity of voltage for impulse withstand tests

The device being tested shall be capable of passing this test with voltages of both positive and negative polarity. Where there is evidence that one polarity (usually the positive) will consistently produce lower withstand voltages on this or similar equipment, it is acceptable to test using only that polarity.

5.6.3 Application of test voltage

Three consecutive impulses of the test voltage specified, with appropriate atmospheric corrections, shall be applied to the device.

5.6.4 Acceptance criteria

If no disruptive discharge occurs during any of the three consecutive impulses, then the device has passed the test. If more than one disruptive discharge occurs, then the device has failed the test. If one disruptive discharge occurs, then nine additional impulses of the test voltage specified are applied, and if no disruptive discharge occurs, then the device has passed the test. If failure occurs in a non-self-restoring part of the insulation, then the device has failed the test.

NOTE—The terminal-to-terminal (open gap) required dielectric withstand values for some devices are 10% higher than those from terminal to ground. However, successful completion of these gap tests does not ensure that a device, when open, will flashover to ground instead of across the open gap.

5.7 Distribution class expulsion type fuses, cutouts, and fuse disconnecting switch test connections and test values

5.7.1 Test conductor arrangement

The bare wires shall project horizontally, at least 30 cm (12 in) from the terminals in a straight line approximately parallel to the face of the crossarm or steel structure, and in such a manner as to not decrease the withstand value. Any necessary bends may be made at the terminals. For enclosed cutouts, the bare wires shall be located approximately in the center of the entrance holes.

5.7.2 Terminal-to-ground tests

For terminal-to-ground tests, the fuse holder, including the conducting element (fuse link or equivalent), shall be in the closed position. The test lead connection shall be made to one of the wires projecting from the terminals. The fuse mounting bracket shall be grounded.

5.7.3 Terminal-to-terminal tests

For terminal-to-terminal tests, the fuse holder, including the conducting element (fuse link or equivalent), shall be in the open position. The test lead connection shall be made to the wire projecting from the upper terminal. The ground test lead connection shall be made to the wire projecting from the lower terminal. The mounting bracket shall not be grounded.

5.7.4 Dielectric test values

The preferred dielectric test values for distribution open, enclosed, and open-link cutouts and fuses are listed in ANSI C37.42.

5.8 Distribution class enclosed single-pole air switch test connections and test values

5.8.1 Test conductor arrangement

The bare wires shall project horizontally at least 30 cm (12 in) from the terminals in a straight line approximately parallel to the face of the crossarm or steel structure, and in such a manner as to not decrease the withstand value. Any necessary bends may be made at the terminals.

5.8.2 Terminal-to-ground tests

For terminal-to-ground tests, the switch blade shall be in the closed position. The test lead connection shall be made to one of the wires projecting from the terminals. The frame of the switch shall be grounded.

5.8.3 Terminal-to-terminal tests

For terminal-to-terminal tests, the switch blade shall be in the open position. The test lead connection shall be made to the wire projecting from the upper terminal. The ground test lead connection shall be made to the wire projecting from the lower terminal. The frame of the switch shall not be grounded.

5.8.4 Dielectric test values

The preferred dielectric test values for distribution enclosed single-pole air switches are listed in IEEE Std C37.45.

5.9 Power class expulsion fuses, power class current-limiting fuses, and power class fuse disconnecting switch test connections and test values

5.9.1 Test conductor arrangement

The conductors shall project from the terminals of the fuse in (substantially) a straight line parallel to the fuse unit or fuse holder for an unsupported distance of at least the break distance of the fuse.

5.9.2 Terminal-to-ground tests

For terminal-to-ground tests, the fuse unit or fuse holder, including the conducting element (fuse link or equivalent), or the disconnecting switch blade, shall be in the closed position. The test lead connection shall be made to one of the wires projecting from the terminals. The base shall be grounded.

5.9.3 Terminal-to-terminal tests

For terminal-to-terminal tests, the fuse unit, fuse holder, or switch blade shall be in one of the following positions:

- a) For fuse disconnecting switches, the fuse unit, fuse holder, or switch blade in the fully open position

- b) For dropout power fuses, with the fuse holder or fuse unit in the dropout position
- c) For non-dropout power fuses, with the fuse holder or fuse unit removed from the support

The high-voltage test lead shall be connected to the wire protruding from the upper terminal, and the ground lead shall be attached to the wire projecting from the lower terminal. The base shall not be grounded.

A power fuse or fuse disconnecting switch rated 72.5 kV and above shall be equipped with standard strength insulator units; one or more insulator units identical to those supporting the current-carrying parts shall be added to each of the insulator supports or columns (only for the test).

A power fuse or fuse disconnecting switch rated 48.3 kV or below shall be mounted with its base insulated from a grounded metal structure by means of insulator units identical to those assembled on the fuse. In the case of a rear-connected indoor power fuse bus, support insulators of equivalent electrical characteristics shall be used to support the base (only for the test).

5.9.4 Dielectric test values

The preferred dielectric test values for all types of indoor and outdoor power fuses are listed in ANSI C37.46.

5.10 Distribution class current-limiting fuse and fuse disconnecting switch test connections and test values

5.10.1 Test conductor arrangement

The conductors shall project from the terminals of the fuse in substantially a straight line parallel to the fuse unit or fuse holder for an unsupported distance of at least the break distance of the fuse.

5.10.2 Terminal-to-ground tests

For terminal-to-ground tests, the fuse unit or fuse holder, including the conducting element (fuse link or equivalent), or the disconnecting switch blade, shall be in the closed position. The test lead connection shall be made to one of the wires projecting from the terminals. The base shall be grounded.

5.10.3 Terminal-to-terminal tests

For terminal-to-terminal tests, the fuse unit, fuse holder, or switch blade shall be in one of the following positions:

- a) For fuse disconnecting switches, the fuse unit, fuse holder, or switch blade in the fully open position
- b) For dropout current-limiting fuses, with the fuse holder or fuse unit in the dropout position
- c) For non-dropout current-limiting fuses, with the fuse holder or the fuse unit removed from the support

The high-voltage test lead shall be connected to the wire protruding from the upper terminal, and the ground lead shall be attached to the wire projecting from the lower terminal. The base shall not be grounded.

5.10.4 Dielectric test values

The preferred dielectric test values for distribution current-limiting fuses are listed in ANSI C37.47.

5.11 Distribution class, power class expulsion and current-limiting type fuses, and fuse disconnecting switches used in FEPs

5.11.1 General

When distribution class and power class expulsion or current-limiting type fuses are used in FEPs, dielectric testing of the complete FEP is required.

5.11.2 Arrangement

All fuses and other apparatus in the enclosure shall be mounted in their normal locations; the conductors shall be in their normal positions and of the size normally used in that enclosure. If the enclosure uses liquid or a gas other than air for the insulating medium, then it should be filled in accordance with the manufacturer's specifications.

5.11.3 Terminal-to-ground tests

- a) For terminal-to-ground tests, the fuse unit(s), fuse holder(s), or the disconnecting blade(s) shall be in the closed position.
- b) Where a fuse link, fuse unit, or refill unit is required to complete the electrical circuit, it may be of any convenient size.
- c) The base and the enclosure, if applicable, shall be grounded.
- d) For multipole devices, all poles shall be tested. They may be energized simultaneously or separately (one at a time).
- e) For devices that can be opened with a part left inserted and hanging in the opened position, an additional test shall be performed. For this test, energize the appropriate terminal(s) that will energize the part(s) that is (are) hanging in the open position. Condition b) through condition d) are applicable for this test.

5.11.4 Terminal-to-terminal tests

- a) For terminal-to-terminal tests, the fuse unit, fuse holder, or disconnecting blade shall be in one of the following positions:
 - 1) For fuse disconnecting switches, the fuse unit, fuse holder, or disconnecting blade in the fully open position
 - 2) For dropout-type fuses, with the fuse unit or fuse holder in the dropout position
 - 3) For non-dropout-type fuses, with the fuse unit or fuse holder removed from the support
- b) Where a fuse link, fuse unit, or refill unit is required to complete the electrical circuit, it may be of any convenient size.
- c) The base or the enclosure, if applicable, shall not be grounded. It may be necessary to insulate the enclosure from ground when the open gap dielectric value exceeds the terminal-to-ground value.
- d) For multipole devices, all poles may be energized simultaneously.

- e) The terminal(s) to be energized are as follows:
 - 1) Incoming terminal(s) with outgoing terminal(s) grounded
 - 2) Outgoing terminal(s) with incoming terminal(s) grounded

If the device is completely symmetrical, only test 1) is required.

5.11.5 Closed-position, pole-to-pole (phase-to-phase) tests for multipole devices

- a) For pole-to-pole closed-position tests, the fuse unit(s), fuse holder(s), or disconnecting blade(s) shall be in the closed position.
- b) Where a fuse link, fuse unit, or refill unit is required to complete the electrical circuit, it may be of any convenient size.
- c) The base and the enclosure, if applicable, shall not be grounded. It may be necessary to insulate the enclosure from ground when the pole-to-pole dielectric value exceeds the terminal-to-ground value.
- d) One pole at a time shall be energized with all other poles grounded. For three-pole devices, if the outer poles are symmetrical with respect to the center pole, then testing of only one outer pole and the center pole is required.

5.11.6 Open-position, pole-to-pole (phase-to-phase) tests for multipole devices

- a) For pole-to-pole open-position tests, the fuse unit, fuse holder, or disconnecting blade shall be in one of the following positions:
 - 1) For fuse disconnecting switches, in the fully open position
 - 2) For dropout-type fuses, with the fuse unit or fuse holder in the dropout position
 - 3) For non-dropout-type fuses, with the fuse unit or fuse holder removed from the support
- b) Where a fuse link, fuse unit, or refill unit is required to complete the electrical circuit, it may be of any convenient size.
- c) The base and the enclosure, if applicable, shall not be grounded. It may be necessary to insulate the enclosure from ground when the pole-to-pole dielectric value exceeds the terminal-to-ground value.
- d) Taking one pole at a time, each end shall be energized separately, with all other poles on that end grounded. For three-pole devices, if the outer poles are symmetrical with respect to the center pole, then testing each end of only one outer pole and each end of the center pole is required.

5.11.7 Dielectric test values

The preferred terminal-to-ground, terminal-to-terminal, and pole-to-pole test values for all types of power class fuses are specified in ANSI C37.46.

The preferred terminal-to-ground, terminal-to-terminal, and pole-to-pole test values for all types of distribution class current-limiting fuses are specified in ANSI C37.47. For all distribution class expulsion type fuses, the values are specified in ANSI C37.42.

5.12 Distribution and power class external fuses for shunt capacitors

5.12.1 Capacitor line fuses

Capacitor line fuses shall be tested per the requirements for the appropriate equipment, as specified in 5.7, 5.9, 5.10, or 5.11.

5.12.2 Capacitor unit fuses

Capacitor unit fuses are normally mounted on the bus of the capacitor bank, or sometimes on one of the bushings of the capacitor. The dielectric strength of the system is determined by the insulation level of the bus of the capacitor bank, the capacitor bushing, and/or the way the fuse is positioned in the system. The dielectric strength of a capacitor unit fuse cannot be evaluated without consideration of the mounting arrangement.

6. Interrupting tests

6.1 Procedures common to all interrupting tests

6.1.1 General

Interrupting test procedures shall be as specified in Clause 4 and as described in Clause 6.

6.1.2 Test circuit

6.1.2.1 Test circuit configuration

The interrupting tests shall be made using a single-phase, alternating-current circuit. The circuit elements used to control the current and X/R ratio shall be in series with each other and the fuse. The testing circuit frequency shall be the rated frequency ± 2 Hz. If 60 Hz test facilities are not available, then tests at 50 Hz ± 2 Hz are acceptable for verifying 60 Hz ratings. Note that 50 Hz tests may produce lower peak let-through currents but may let through more I^2t than 60 Hz tests.

The parameters of the test circuits and other testing information are specified in Table 6 through Table 20 and the associated clauses. The current applied to a tested device is specified as a prospective or test current. These current parameters given in Table 6, Table 7, Table 8, Table 11, Table 14, Table 17, Table 19, and Table 20 are expressed in symmetrical amperes. However, the test circuit will provide a symmetrical or associated asymmetrical short-circuit current, depending on the making angle, as required by the appropriate table. Where an asymmetrical current is produced, it shall be equal to or greater than the asymmetrical current associated with the symmetrical current and X/R ratio specified in the appropriate table (see Figure C.1). If tests are made at an X/R ratio higher than is specified in the appropriate table, then the test duty may be more severe, because the prospective asymmetrical current will be equal to or greater than the asymmetrical current associated with the symmetrical current and specified X/R ratio. However, it is not permissible to decrease the prospective symmetrical current to achieve the proper asymmetrical current value.

Typical test circuits are shown in Figure D.1. Methods of determining transient recovery voltage (TRV) parameters are also shown in Annex D. Overvoltage protective equipment used for protecting test circuit apparatus shall not significantly affect the current through the fuse or the recovery voltage across the fuse.