

IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories

Sponsor

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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, making-current, 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, high-voltage fuses

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Introduction

(This introduction is not part of IEEE Std C37.41-2000, IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.)

IEEE Std C37.41-2000 is a revision of IEEE Std C37.41-1994, in order to bring it up to date and into agreement with current requirements for high-voltage fuses and switches. Previously approved supplements have been incorporated. The standard was prepared by the IEEE Subcommittee on High-Voltage Fuses, with cooperation from the National Electrical Manufacturers Association (NEMA).

This standard is one of a series of complementary standards covering various types of high-voltage fuses and switches, so arranged that two of the standards apply to all devices, while each of the other standards provide additional specifications for a particular device. For each device, IEEE Std C37.40-1993, IEEE Std C37.41-2000, plus the standard covering that device, constitute a complete set of standards for each device. In addition, IEEE Std C37.48-1997 is an application, operation, and maintenance guide for all the devices.

The following standards comprise this series:

ANSI C37.42-1996, American National Standard for Switchgear—Distribution Cutouts and Fuse Links—Specifications.

ANSI C37.44-1981 (Reaff 1987), American National Standard Specifications for Distribution Oil Cutouts and Fuse Links.

ANSI C37.45-1981 (Reaff 1987), American National Standard Specifications for Distribution Enclosed Single-Pole Air Switches.

ANSI C37.46-2000, American National Standard Specifications for Power Fuses and Fuse Disconnecting Switches.

ANSI C37.47-2000, American National Standard Specifications for Distribution Fuses and Fuse Disconnecting Switches Fuse Supports, and Current-Limiting Fuses.

IEEE Std C37.40-1993, IEEE Standard Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories (ANSI).

IEEE Std C37.41-2000, IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories (ANSI).

IEEE Std C37.48-1997, IEEE Guide for Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories (ANSI).

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IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories

1. Scope

1.1 Fuses and fuse equipment

This standard specifies design test requirements for high-voltage (above 1000 V) fuses, distribution enclosed single-pole air switches, fuse disconnecting switches, and accessories for use on alternating-current distribution systems. 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 (see types listed in 1.2 and 1.3)
- e) Fuse supports, fuse mountings, and fuse hooks of the type intended for use with distribution and power class fuses, and fuse disconnecting switches
- f) Removable switch blades of the type used exclusively with distribution class oil cutouts, power class fuses, and distribution class fuse disconnecting switches
- g) Fuse links when used exclusively with distribution class oil cutouts, power class fuses, and distribution class fuse disconnecting switches
- h) Distribution class oil cutouts
- i) Distribution class enclosed single-pole air switches
- j) Distribution and power classes of expulsion, current-limiting, and combination external capacitor type fuses used with a capacitor unit, groups of units, or capacitor banks.

The distribution and power class expulsion type fuses listed previously in item a) through item j) are the same as those covered in IEC 60282-2 (1995-09)¹. The distribution class expulsion type fuses are the same as the IEC 60282-2 class “A” fuses, and the power class fuses are the same as the IEC 60282-2 class “B” fuses. At present, IEEE standards do not cover the class “C” fuses listed in IEC 60282-2 (1995-09). Some of the current-limiting type fuses listed above are the same as those covered in IEC 60282-1 (1994-12). IEEE Std C37.41-2000 contains specific requirements for more types of current-limiting fuses than are covered in IEC 60282-1 (1994-12). Use caution if devices specified and tested per ANSI/IEEE standards are compared to those specified and tested per IEC standards, as they may or may not be the same.

1.2 Description of fuse-enclosure packages (FEP) 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 switchgear enclosure).

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

Type 1C: A fuse mounted in an 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).

Type 2C: A fuse in a container mounted in an enclosure with restricted air flow surrounding the fuse, but with relatively free air circulation within the enclosure on the outside surfaces of the container (e.g., a fuse inside a canister in an enclosure or a vault).

Type 3C: A fuse in a container mounted in an enclosure with restricted air flow surrounding the fuse, but relatively free liquid circulating within the enclosure on the outside surfaces of the container (e.g., a fuse inside a canister immersed in transformer oil).

Type 4C: A combination of Types 2C and 3C, where the container is partially in air and partially in liquid (e.g., a fuse inside a transformer bushing).

Type 5C: 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).

2. References

2.1 American National Standards

This standard shall be used in conjunction with the following American National Standards. Although some of the following standards may be superseded by a revision approved by the American National Standards Institute, the revision may **not** apply.

¹Information on references can be found in Clause 2.

ANSI C37.42-1996, American National Standard for Switchgear—Distribution Cutouts and Fuse Links—Specifications.²

ANSI C37.44-1981 (Reaff 1987), American National Standard Specifications for Distribution Oil Cutouts and Fuse Links.

ANSI C37.45-1981 (Reaff 1987), American National Standard Specifications for Distribution Enclosed Single-Pole Air Switches.

ANSI C37.46-2000, American National Standard Specifications for Power Fuses and Fuse Disconnecting Switches.

ANSI C37.47-2000, American National Standard Specifications for Distribution Fuses and Fuse Disconnecting Switches Fuse Supports, and Current-Limiting Fuses.

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

IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.³

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing (ANSI).⁴

IEEE Std C37.20.3-1987 (Reaff 1992), IEEE Standard for Metal-Enclosed Interrupter Switchgear (ANSI).

IEEE Std C37.40-1993, IEEE Standard Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fused Disconnecting Switches, and Accessories (ANSI).

IEEE Std C37.48-1997, IEEE Guide for Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories (ANSI).

2.2 Other standards

IEC 60282-1 (1994-12), High-voltage fuses—Part 1: Current-limiting fuses.⁵

IEC 60282-2 (1995-09), High-voltage fuses—Part 2: Expulsion fuses.

3. Required tests

The tests to be conducted upon completion of a design, or following a design change that affects performance, are summarized in Table 1⁶ and are completely specified in the appropriate standards listed below:

- ANSI C37.42-1996
- ANSI C37.44-1981
- ANSI C37.45-1981
- ANSI C37.46-2000
- ANSI C37.47-2000

²ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³IEEE Std 4-1978 has been superseded; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.standards.ieee.org/>).

⁵IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁶Tables have been placed after Clause 15.

3.1 Device tests

For devices covered by this standard, all applicable tests need not be performed on each design modification of a previous 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.

3.2 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.

3.3 Test values

3.3.1 Allowable tolerances

Testing parameters in this document and the specification documents for each device are listed as a value with an allowable plus tolerance, a value with an allowable minus tolerance, a minimum 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. When 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 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.

3.3.2 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 ratings and performance requirements shall be agreed upon by the user and the manufacturer.

3.4 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.

4. Common test requirements

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.

4.1 Test site conditions

4.1.1 Ambient temperature during test

The ambient temperature prevailing at the test site shall conform to usual service conditions, in accordance with 2.1 of IEEE Std C37.40-1993.

4.1.2 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.

4.2 Frequency and wave shape of test voltage

4.2.1 Frequency of test voltage

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

4.2.2 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.

4.3 Devices to be tested

4.3.1 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.

4.3.2 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.

4.4 Acceptance criteria

After successful completion of the required tests listed in this standard, and after replacing parts that are normally field replaceable, excluding the fuse holder, the condition of the device shall be as follows:

- a) **Mechanically:** 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.
- b) **Electrically:** Capable of carrying rated current continuously at the rated maximum voltage. If there is evidence to suggest the device may not be able to continuously carry rated current 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 criteria for acceptability is long-term temperature stabilization.

- c) **Dielectrically:** If there is evidence of insulator contamination from the test, a power-frequency dry-withstand test shall be performed at 75% of the rated value for the device.

NOTE—Examples of parts that are normally field replaceable include the fuse link, refill unit, expendable cap, and exhaust control device.

4.5 Test-conductor dimensions

4.5.1 Interrupting, load-break, making-current, 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 adequately carry the test current 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 different under normal service conditions or as specified by the manufacturer's recommendations.

4.5.2 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.

4.5.3 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 17.

4.6 Mounting and grounding of the device for tests

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, current metering devices or short gaps shunted by a fine wire may be used. Specific mounting and grounding information for the various devices to be tested is described in 4.6.1 through 4.6.7.

4.6.1 Distribution class expulsion type fuses, cutouts, and 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 (3.5 in × 4.5 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.

4.6.2 Distribution class oil cutouts

Distribution class oil cutouts shall be mounted on a rigid structure. The housing shall be grounded.

4.6.3 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 (3.5 in × 4.5 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.

4.6.4 Power class expulsion and current-limiting fuses and fuse-disconnecting switches

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

4.6.5 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.

4.6.6 Distribution and power class fuses and fuse-disconnecting switches used in FEPs

Distribution and 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.

4.6.7 Distribution and power class external fuses for shunt capacitors

4.6.7.1 Capacitor line fuses

The fuse equipment shall be mounted as specified in 4.6.1, 4.6.4, 4.6.5, or 4.6.6.

4.6.7.2 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

In this clause, IEEE Std 4-1978 and IEEE Std 4-1995 are used as references. The 1978 version is preferred, due to long field experience, but testing to the 1995 version, at the manufacturer's option, is also fully acceptable for the purposes of meeting this standard.

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

5.1 Measurement of test voltages

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

5.2 Description of power-frequency dry-withstand voltage tests

5.2.1 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.

5.2.2 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.

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

5.3.1 Application of test voltage

The test voltage specified, with appropriate atmospheric corrections, shall be applied to the device per IEEE Std 4. 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.

5.3.2 Application of test precipitation

Precipitation shall be applied per IEEE Std 4. In addition, 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.

5.3.3 Acceptance criteria

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

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

5.4.1 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°C to -15°C until it is thoroughly cooled (may take 10–12 h). The device shall then be mounted in a test chamber having a normal temperature of 22°C to 25°C and a humidity of approximately 100%. When the device is completely covered with dew, the test voltage as specified in 5.4.2 shall be immediately applied.

5.4.2 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.

5.4.3 Acceptance criteria

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

5.5 Description of impulse-withstand voltage tests

5.5.1 Impulse test voltage wave shape

The wave shape and application of the 1.2/50 μ s full wave test voltage is described in IEEE Std 4 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 μ s, a crest voltage greater than or equal to the rated full wave impulse withstand voltage, and a time, from initiation, of at least 50 μ s for the voltage to fall to 50% of the crest value.

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

5.5.2 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.

5.5.3 Application of test voltage

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

5.5.4 Acceptance criteria

If no disruptive discharge occurs during any of the three consecutive impulses, the device has passed the test. If more than one disruptive discharge occurs, 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, the device has passed the test. If failure occurs in a non-self-restoring part of the insulation, 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.

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

5.6.1 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.

5.6.2 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.

5.6.3 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.

5.6.4 Dielectric test values

The preferred dielectric test values for distribution open, enclosed, and open-link cutouts and fuses are listed in Table 2 of ANSI C37.42-1996.

5.7 Distribution class oil cutout test connections and test values

5.7.1 Test conductor arrangement

The conductor shall be connected to each terminal, to the end of the full length of insulated cables furnished with the cutout, or to the end of an insulated cable attached to the terminal in accordance with the manufacturer's instructions. Entrance terminals requiring taping or compound filling shall be assembled and taped or filled in accordance with the manufacturer's instructions. The connections coming from the cutout shall not approach the metal parts of the cutout closer than a projection of the center line of the entrance terminal. Insulated conductors shall terminate 30 cm (12 in) or more from any grounded metal member of the terminal or of a cable sheathing attached to the grounded metal member in the normal assembly thereof.

5.7.2 Terminal-to-ground tests

For terminal-to-ground tests, the 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. All groundable metal parts shall be grounded.

5.7.3 Dielectric test values

For terminal-to-ground tests, the preferred dielectric test values for distribution oil cutouts are listed in Table 3 of ANSI C37.44-1981.

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 Table 2 of ANSI C37.45-1981.

5.9 Power class expulsion and current-limiting fuse, and 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 outdoor power fuses are listed in Table 3 of ANSI C37.46-2000; for all types of indoor power fuses, the preferred dielectric test values are listed in Table 4 of ANSI C37.46-2000.

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 Table 2 of ANSI C37.47-2000.

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

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

5.11.1 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, it should be filled in accordance with the manufacturer's specifications.

5.11.2 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. Conditions b), c), and d) above are applicable for this test.

5.11.3 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
 - 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.

5.11.4 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, testing of only one outer pole and the center pole is required.

5.11.5 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, testing each end of only one outer pole and each end of the center pole is required.

5.11.6 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 Table 4 of ANSI C37.46-1981.

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 Table 3 of ANSI C37.47-1981. For all distribution class expulsion type fuses, the values are specified in Table 2 of ANSI C37.42-1996.

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 either 5.6, 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, without consideration of the mounting arrangement, is not definable.

6. Interrupting tests

6.1 Procedures common to all interrupting tests

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

6.1.1 Test circuit

6.1.1.1 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, 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 are specified in Tables 2 through 16. The prospective (available) current parameters given in Tables 2, 3, 5, 6, 9, 12, 13, and 16 are expressed in symmetrical amperes. The test circuit must provide a symmetrical short-circuit current as required by the appropriate table. Also, the asymmetrical current must 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. 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 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.

6.1.1.2 Determination of the X/R ratio and the prospective (available) short-circuit current of the test circuit

The device to be tested shall be replaced in the test circuit with a connection having negligible impedance. For interrupting tests involving short melting times of the fusible element (i.e., less than or equal to 1.5 cycles), both the X/R ratio and the prospective symmetrical short-circuit current shall be determined as follows.

To determine the symmetrical short-circuit current, power shall be applied at the point on the voltage wave that minimizes the offset in the first loop (i.e., power should be applied at an angle approximately equal to the value of the $\arctan[X/R]$ with respect to voltage zero, where X/R is the estimated X/R ratio of the test circuit). The symmetrical current may be calculated in accordance with Figure A.1. The root-mean-square (rms) current should be measured during the first cycle of current.

To determine the rms asymmetrical short-circuit current, the power shall be applied at the point on the voltage wave (i.e., near a voltage zero) that produces maximum offset in the first current loop. The rms total asymmetrical current, including the direct-current component as measured at the time of the first major peak, should be determined. This may be accomplished by following the methods described in Annex A.

Determination of the test-circuit symmetrical current may be combined with the asymmetrical current determination, provided that the circuit current is of sufficiently long duration so the symmetrical current component has achieved a steady-state value (i.e., the symmetrical current value is constant between cycles). This may be accomplished by following the methods described in Annex A.

After the symmetrical and asymmetrical short-circuit current values are obtained, the X/R ratio of the test circuit may be determined by calculating the ratio of the rms asymmetrical current to the rms symmetrical current component (see Figure C.1).

For interrupting tests involving long melting times of the fusible element (i.e., greater than 1.5 cycles), it may be appropriate to use alternate methods to determine the circuit X/R ratio. For these tests, the rms value of the current shall be measured immediately prior to the initiation of arcing.

6.1.1.3 Application of test power

The device shall be tested in the circuit described in 6.1.1.1 and 6.1.1.2, with the negligible impedance connection removed. Power shall be applied at a point on the voltage wave that produces the conditions specified in the appropriate table covering the particular device being tested.

6.1.2 Acceptance criteria

The condition of the device after interrupting tests shall be as specified in 4.4.

6.2 Description of interrupting tests on distribution class open-link cutouts

Tests shall be made at the rated maximum voltage in accordance with Table 2. A description of the required test series is as follows:

- *Series 1:* Verification of fuse operation with prospective currents equal to its rated interrupting current.
- *Series 2:* Under consideration.
- *Series 3:* Verification of fuse operation with small overload currents.

6.3 Description of interrupting tests on distribution class oil cutouts

Tests shall be made at the rated maximum voltage in accordance with Table 3. A description of the required test series is as follows:

- *Series 1:* Verification of fuse operation with prospective currents equal to its rated interrupting current.
- *Series 2:* Under consideration.
- *Series 3:* Under consideration.
- *Series 4:* Verification of fuse operation with small overload currents.

6.4 Description of interrupting tests on distribution class fuse cutouts (open and enclosed) (except current-limiting fuses)

6.4.1 Test series for single-voltage-rated fuse cutouts

Tests shall be made at the rated maximum voltage in accordance with Table 5. A description of the required test series is as follows:

- *Series 1:* Verification of fuse operation with prospective currents equal to its rated interrupting current.
- *Series 2:* Verification of fuse operation with the prospective currents ranging from 70% to 80% of its rated interrupting current.
- *Series 3:* Verification of fuse operation with prospective currents ranging from 20% to 30% of its rated interrupting current.
- *Series 4:* Verification of fuse operation with prospective currents in the range of 400–500 A.
- *Series 5:* Verification of fuse operation with small overload currents.

6.4.2 Test series for slant-voltage-rated (multiple-voltage-rated) fuse cutouts (example: 15/27 kV)

Tests shall be made at the rated maximum voltages specified and in accordance with Table 6. A description of the required test series is as follows:

- *Series 1:* Verification of fuse operation with prospective currents equal to its rated interrupting current and conducted at its maximum voltage to the left of the slant.
- *Series 2:* Verification of fuse operation with prospective currents ranging from 70% to 80% of its rated interrupting current and conducted at its maximum voltage to the left of the slant.
- *Series 3:* Verification of fuse operation with prospective currents ranging from 20% to 30% of its rated interrupting current and conducted at its maximum voltage to the right of the slant.
- *Series 4:* Verification of fuse operation with prospective currents in the range of 400–500 A and conducted at its maximum voltage to the right of the slant.
- *Series 5:* Verification of fuse operation with small overload currents and conducted at its maximum voltage to the right of the slant.
- *Series 6:* Verification of fuse operation of two fuse cutouts in electrical series connection with prospective currents equal to the rated interrupting current of both series devices and conducted at its maximum rated voltage to the right of the slant.

6.5 Description of interrupting tests on power class fuses and fuse-disconnecting switches (except current-limiting fuses and liquid-submerged power fuses)

Tests shall be made at the voltages specified and in accordance with Table 9. A description of the required test series is as follows:

- *Series 1:* Verification of fuse operation with prospective currents equal to its rated interrupting current and conducted at 87% of its rated maximum voltage.
- *Series 2:* Verification of fuse operation with prospective currents ranging from 87% to 91% of its rated interrupting current and conducted at its rated maximum voltage.
- *Series 3:* Verification of fuse operation with prospective currents ranging from 60% to 70% of its rated interrupting current and conducted at its rated maximum voltage.
- *Series 4:* Verification of fuse operation with prospective currents ranging from 20% to 30% of its rated interrupting current and conducted at its rated maximum voltage.
- *Series 5:* Verification of fuse operation with prospective currents in the 400–500 A range and conducted at its rated maximum voltage.
- *Series 6:* Verification of fuse operation with small overload currents and conducted at its rated maximum voltage.

6.6 Description of interrupting tests on current-limiting power and distribution fuses

6.6.1 Test series

Tests shall be made at the voltages specified and in accordance with Table 12. Descriptions of the required test series are as follows.