

IEEE Standard for Design Tests and Specifications for High-Voltage (> 1000 V) Fuses and Accessories

IEEE Power and Energy Society

Developed by the
Switchgear Committee

IEEE Std C37.41™-2024
(Revision of IEEE Std C37.41-2016)

STANDARDS

IEEE Standard for Design Tests and Specifications for High-Voltage (> 1000 V) Fuses and Accessories

Developed by the

Switchgear Committee
of the
IEEE Power and Energy Society

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Abstract: Required procedures for performing design tests for high-voltage fuses, as well as for fuse disconnecting switches, are specified. These design tests, as appropriate to a particular device, include the following test types: dielectric, interrupting, radio-influence, temperature-rise, time-current, manual-operation, liquid-tightness, thermal-cycle, bolt-torque, withstand tests for motor circuit fuses, expulsion fuses using polymeric insulators, load-break, and short-time current.

Keywords: FEP, fuse accessories, fuse design tests, fuse disconnecting switches, fuse-enclosure package, high-voltage fuses, IEEE C37.41™

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Introduction

This introduction is not part of IEEE Std C37.41-2024, IEEE Standard for Design Tests and Specifications for High-Voltage (> 1000 V) Fuses and Accessories.

IEEE Std C37.41™-2024 is a revision of IEEE Std C37.41-2016 and its corrigenda, IEEE Std C37.41-2016/Cor 1-2017. It has been done in order to incorporate the specification standard IEEE Std C37.42™-2016, the aim being to have all information necessary to test fuses and accessories, within the scope of the IEEE fuse standards, into one document to increase “user friendliness.” The opportunity has been taken to review all testing requirements in order to bring it up to date and into agreement with current requirements for high-voltage fuses and switches. The Revision of Fuse Standards—C37.41 Working Group of the IEEE Subcommittee on High-Voltage Fuses prepared the standard. Liaison was maintained with the IEC during the development of the revisions in order to incorporate the latest activities at the time of publication (liaison has been maintained by having WG members also be members of the relevant working groups and maintenance teams of the IEC high-voltage fuse subcommittee, SC32A).

This standard is one of a, now simplified, series of complementary standards covering various types of high-voltage fuses and switches. IEEE Std C37.45™-2016 contains all the testing requirements and specifications for high-voltage distribution class enclosed single-pole air switches. IEEE Std C37.41-2024 and IEEE Std C37.45-2016, therefore, provide all the testing requirements for a covered device. In addition, IEEE Std C37.48™-2020 provides tutorial information together with application, operation, and maintenance guidance for all the devices covered by IEEE Std C37.41 and limited information concerning various other fuses and fuse related devices used throughout the world.

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

- IEEE Std C37.41-2024, IEEE Standard for Design Tests and Specifications for High-Voltage (> 1000 V) Fuses and Accessories.
- IEEE Std C37.45-2016, IEEE Standard for Design Test Specifications for High-Voltage (> 1000 V) Distribution Class Enclosed Single-Pole Air Switches.
- IEEE Std C37.48-2020, IEEE Guide and Tutorial for the Application of High-Voltage (> 1000 V) Fuses and Accessories.

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IEEE Standard for Design Tests and Specifications for High-Voltage (> 1000 V) Fuses and Accessories

1. Overview

1.1 Scope

This standard establishes design tests and specifications for high-voltage (above 1000 V) fuses and accessories for use on ac electrical distribution systems. Devices with rated maximum voltages to 170 kV are covered. The devices to which this standard applies are as follows:

- a) Expulsion fuses (including fuse cutouts)
- b) Current-limiting fuses
- c) Items a) and b) used in fuse-enclosure packages
- d) Fuse supports of the type intended for use with fuses and fuse disconnecting switches
- e) Disconnecting devices (fuse disconnecting switches, disconnecting switches, and disconnecting cutouts) created by the use of a removable fuse unit or switch blade in a fuse support
- f) Expulsion, current-limiting, and combination types of external capacitor fuses used with a capacitor unit, a group of units, or capacitor banks
- g) Backup current-limiting fuses (“motor-starter fuses”) used in conjunction with high-voltage motor starters
- h) Fuse links when used exclusively with expulsion fuses and fuse disconnecting switches
- i) Items a) through f) having integral load-break means
- j) Accessories including mounting brackets and switch sticks (switch hooks)

This standard may also be used as a basis for testing other devices that are similar to the devices listed in the scope. In addition, the parts relating to expulsion fuses may, where applicable, be used for non-expulsion fuses in which the interruption process waits for a natural current zero to clear the circuit.

1.2 Purpose

This standard contains the specifications and minimum testing requirements for fuses and related devices. Such standardization is needed to help ensure uniform minimum product testing for, and consistent development and application of, devices within the document scope. Test areas covered are based on historical experience.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

1.4 Comparisons with IEC fuse standards

1.4.1 General

The testing prescribed in this standard generally follows the fuse-testing requirements found in IEC high-voltage (HV) fuse standards. However, significant differences exist between the requirements of this document and those of IEC (see 1.4.3 and 1.4.4 for some examples of these differences). As a result of the differences, the user is advised to exercise 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 could result in devices tested to IEC not being suitable for applications where devices tested to IEEE/ANSI standards are required (or vice versa).

1.4.2 Terminology

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 could 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. The differences in terminology usage between IEEE and IEC fuse standards are a potential source of confusion. This might cause a user to misunderstand a fuse's capability if it is used in an application for which the standard was not written. For comparisons of terminology and testing methods, see IEEE Std C37.48™ and its companion document IEC TR 62655 [B9] (both are very similar tutorial and application guides for HV fuses and were produced with close cooperation between IEEE and IEC).^{8,9}

1.4.3 Expulsion fuses

Many expulsion fuses listed in 1.1 are covered in IEC 60282-2:2008 [B7]. The test requirements for Class A {distribution class}¹⁰ expulsion fuses are similar to the requirements for IEC class “A” fuses, with the exception of Test Series 4. The IEEE requirements for Test Series 4 include additional tests; see Clause 9 and Annex J. The Class B {power class} expulsion fuse requirements are similar to the IEC class “B” fuse requirements. However, several minor differences exist between the specified testing requirements of IEC and ANSI/IEEE. There are more significant differences in the types of testing covered (for example IEC

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

⁸ Information on references can be found in Clause 2.

⁹ The numbers in brackets correspond to those of the bibliography in Annex K.

¹⁰ 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.

includes no specific testing for expulsion fuses in enclosures). Certain fuses common in North American practice, but not covered by IEC 60282-2 (e.g., open-link cutouts), are included in Annex A of this standard.

1.4.4 Current-limiting fuses

Testing requirements for current-limiting fuses listed in 1.1 are similar to those covered in IEC 60282-1:2020 [B6] when tested using Series II voltages (“North American practice”). However, differences exist for IEC interrupting (breaking) current testing at voltages classed as “Series I” (European practice) and also in the case of editions of IEC 60282-1 prior to the 2020 Edition 8 for fuses having voltages classed as “Series II.” This is because such IEC testing is designed specifically to cover applications in effectively-grounded-neutral three-phase systems. As a result, some IEC tests are/were performed at a lower voltage compared to IEEE. Other differences include different or no IEC testing for certain fuses intended for use in a surrounding temperature above 40 °C. Also, IEEE standards divide current-limiting fuses into Class A and Class B (in a similar way that IEC divides expulsion fuses). IEEE Std C37.41 has X/R values higher for Class B than Class A, while the single test requirements of IEC 60282-1 encompass the requirements of the two separate IEEE classes.

1.4.5 Capacitor fuses

Testing for expulsion, current-limiting, and combination types of fuses listed in 1.1 for protecting shunt capacitors is similar to that covered in IEC 60549 [B8], which references IEC 60282-1 [B6] and IEC 60282-2 [B7]. Fuses used for the protection of shunt capacitors are either line {group} fuses or unit {individual} fuses.

Line fuses are used for the protection of one phase of a capacitor bank that might have one capacitor unit or multiple capacitor units per phase.

Unit fuses are used for the protection of one capacitor unit and are generally used in capacitor banks that have many capacitor units per phase. Unit fuses are used only for capacitor protection and are designed so that they are generally mounted on the bus bar of the capacitor bank.

1.5 Description of fuse-enclosure packages (FEPs)

1.5.1 FEPs using expulsion indoor Class B 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). The relevant fuse rated maximum application temperature (RMAT) is based on that of the air that is cooling the fuse.
- Type 2E: A fuse mounted in a container with restricted airflow 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 airflow). The relevant fuse RMAT is based on that of the air on the outside of the container.
- 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, see A.3.5). The relevant fuse RMAT is based on that of the liquid in contact with the fuse.

1.5.2 FEPs using current-limiting indoor 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 RMAT is based on that of the air that is cooling the fuse. It can 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 (canister). 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 9.3 (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, used for additional testing, is based on the temperature 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 fuse RMAT is based on that of the liquid in contact with the fuse.

1.6 Interchangeability considerations

Due to the wide variation in fuse types, interchangeability guidelines have little meaning. Complete mechanical and electrical interchangeability cannot be assured and would need to be determined by agreement between the manufacturer and user. Clause 19, construction requirements, specifies some critical dimensions for various fuse types. Annex G contains specifics for mounting brackets, and Annex H contains construction requirements for switch sticks. While these sections contain no requirements for fuses, all applicable fuses shall be designed to accommodate these specifications.

Standard ratings, such as “T” and “K” defined in 12.3.3.2, provide a level of time-current characteristic conformance, sufficient for many applications. However, standard ratings such as “C,” “E,” or “R” defined in A.5 of this standard only provide a basic level of time-current characteristic conformance and do not provide enough information to ensure proper application and coordination of fuses. This is particularly true when different fuse types or fuses from different manufacturers are being applied together. Published information, such as current ratings and time-current characteristic curves, should be used to select fuses, following the manufacturer’s recommendations. If there are specific questions, the manufacturer should be consulted.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so 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 C63.2, American National Standard for Specifications of Electromagnetic Interference and Field Strength Measuring Instrumentation in the Frequency Range 9 kHz to 40 GHz.¹¹

ANSI/NEMA 107, Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus.

ASTM D2240-15, Standard Test Method for Rubber Property—Durometer Hardness.¹²

ASTM G154, Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Materials.

¹¹ ANSI publications are available from the American National Standards Institute (<https://www.ansi.org/>).

¹² ASTM publications are available from the American Society for Testing and Materials (<https://www.astm.org/>).

IEEE Std 4™, IEEE Standard for High-Voltage Testing Techniques.^{13,14}

IEEE Std C37.20.3™, IEEE Standard for Metal-Enclosed Interrupter Switchgear Rated above 1 kV AC up to and Including 48.3 kV AC.

IEEE Std C37.48™, IEEE Guide and Tutorial for the Application of High-Voltage (> 1000 V) Fuses and Accessories.

IEEE Std C37.100.1™, IEEE Standard for Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹⁵

allowable continuous current (I_a): The designated value of constant rms current, in amperes, at rated frequency, assigned to a device by the manufacturer, at a specified ambient temperature, based on maximum component temperatures. *See also:* **maximum enclosure current; rated current.**

NOTE—Allowable continuous current values might be higher than, equal to, or lower than the assigned rated current (I_r). For example, higher values of allowable continuous current are often associated with Class A fuses fitted with certain fuse links, while lower values of allowable continuous current are often associated with elevated ambient temperatures and specific application conditions. A device could have several allowable continuous currents specified (each at a different ambient temperature) or allowable continuous current might be defined by a formula related to ambient temperature.¹⁶

ambient temperature: The temperature of the surrounding medium that comes in contact with the device or equipment.

arcing time (of a fuse): The time that elapses from the initiation of arcing in the fuse element(s) to the final interruption of the circuit, that is, the length of the time that the fuse arcs.

available current: *See:* **prospective current.**

NOTE—The term *available* has been used in the past and is considered identical in meaning to *prospective*.

backup current-limiting fuse: *See:* **current-limiting fuse.**

barrier: A partition for the insulation or isolation of electric circuits or electric arcs.

base: The supporting member of a fuse support to which the insulator unit or units are attached. A base also normally has a means for attaching the fuse support to crossarm(s) or other mounting structure(s).

basic impulse insulation level (BIL): Previously used term (still in common usage) for rated lightning impulse withstand voltage. *Syn:* **rated lightning impulse withstand voltage.**

blade; disconnecting blade (of a disconnecting switch or disconnecting cutout): A nonfusible electrically conducting part that, when in the closed position, bridges the fixed or stationary contacts or contact clips of the switch or cutout, allowing current to be conducted through the device. Removing or repositioning this conducting part prevents current from flowing through the device.

break distance (of a device): The minimum open-gap distance between the main circuit contacts, or conducting parts connected to them, when the device is in the full-open position.

¹³ The IEEE standards or products referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

¹⁴ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹⁵ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹⁶ Notes to text, tables, and figures are for information only and do not contain requirements needed to implement the standard.

capacitive interrupting current: Current for which the specified conditions of use and behavior include the opening of the circuit that includes capacitor elements and/or capacitor units in series with the fuse.

capacitor bank: A number of capacitor units connected so as to act together.

capacitor element: The basic component of a capacitor unit consisting of two electrodes separated by a dielectric.

capacitor line fuse: A fuse applied to disconnect a faulted phase of a capacitor bank from a power system.

capacitor unit: An assembly of one or more capacitor elements in the same container with one set of external terminals.

capacitor unit fuse: A fuse applied to disconnect an individual faulted capacitor unit from its bank.

clearing time (of a fuse): The time that elapses from the initiation of a current that will melt the fuse element to the final interruption of the circuit.

NOTE 1—Clearing time is the sum of the melting time and the arcing time.

NOTE 2—Maximum clearing time-current-characteristic curves are developed at rated maximum voltage for the device.

NOTE 3—{operating time; total clearing time}; see 1.4.2.

composite polymeric insulator: A polymeric insulator consisting of at least two separate non-ceramic insulating parts, namely a core and a housing, equipped with end fittings.

conformance tests (for fuses): Those tests that are specifically made to demonstrate that fuses, or fuse-related components, meet certain requirements of applicable standards.

NOTE—This is typically needed when the device is used with other equipment that requires third-party certification.

contacts (for fuses and fuse-related components): The current carrying components that make electrical connection between a fuseholder, fuse unit, disconnecting blade, fuse support, or other conducting means, whereby the fuse component that includes the fusible means, or a blade, can be connected into a circuit. *See also: fuse support contacts.*

core (of a composite polymeric insulator): The central insulating part of a composite polymeric insulator that provides the primary mechanical/strength characteristics of the insulator.

current-limiting fuse; current-limiting fuse unit: A fuse that, when its fuse element(s) is (are) melted by a current within its specified current-limiting range, abruptly introduces sufficient resistance into the circuit such that the first current peak is reduced. The current is interrupted significantly earlier than the normal current zero of the circuit, and the fuse subsequently withstands the circuit's recovery voltage.

NOTE 1—The ratio of actual peak current to prospective peak current decreases significantly as the prospective current increases from the value where current-limitation first occurs (threshold current) up to the rated maximum interrupting current of the fuse.

NOTE 2—Measures of the current-limiting ability of fuses include the ratio of threshold current to rated current (threshold ratio), peak let-through current versus prospective short-circuit current characteristic curves, and I^2t characteristics. Values of some or all of these parameters should be available from the fuse manufacturer.

NOTE 3—Current-limiting fuses are divided into two classes, Class A and Class B (see **fuse classification**), based on acceptable circuit parameters when in their current-limiting mode, and can also be divided into three types, backup, general-purpose, and full-range, based on their interrupting capability at currents below their threshold current.

(A) **backup current-limiting fuse:** A current-limiting fuse capable of interrupting, under specified conditions of use and behavior, all currents from its rated maximum interrupting current down to its rated minimum interrupting current.

(B) **general-purpose current-limiting fuse:** A current-limiting fuse capable of interrupting, under specified conditions of use and behavior, all currents from its rated maximum interrupting current down to a low value equal to the current that causes melting of the fuse element(s) in one hour.

(C) full-range current-limiting fuse: A current-limiting fuse capable of interrupting, under specified conditions of use and behavior, all currents that cause melting of the fuse element(s) up to its rated maximum interrupting current.

NOTE—For the purpose of demonstrating its ability to interrupt low currents, the full-range current-limiting fuse is required to interrupt a “minimum test current” (I_3) when it is applied at the maximum ambient temperature specified by the manufacturer (RMAT).

cutout: A Class A {distribution class} device consisting of a fuse support and a conducting member that can be rotated into an “open” position, where it can be removed from the fuse support.

NOTE—Cutouts are generally supplied with a mounting bracket (see Annex G) that is suitable for crossarm or wall mounting. Other mounting arrangements might be available.

Cutouts are divided into the following types:

(A) Fuse cutout: This is a cutout using a fuseholder lined with gas-evolving material that participates in the expulsion process at high fault currents. A fuse link (normally supplied separately) is assembled into the fuseholder. It is a Class A dropout expulsion fuse and is a fuse disconnecting switch.

(B) Open cutout: A cutout where the live parts of the device are exposed.

(C) Enclosed cutout: A cutout in which the live parts are completely contained within an insulating enclosure. When fitted with a fuseholder and fuse link, it might or might not be a dropout device. Some devices drop open, or the tube might drop down, to indicate it has operated. When fitted with a solid metal blade, forming a disconnecting device, it might also have a provision to show if the blade is not connected into the circuit.

(D) Load-break cutout: A cutout with means for interrupting load currents.

NOTE 1—Cutouts are not inherently load-breaking devices unless fitted with a load-breaking means. Such means include a device that will break the fuse link, causing a fuse cutout to interrupt the load current, or a load-break device (e.g., an arc chute) as part of the fuse support, used with a special fuseholder.

NOTE 2—It does not apply to devices that can be operated with a portable load-break device.

(E) Cutout-mounted current-limiting fuse: A current-limiting fuse, mounted in a cutout fuse support, that is a dropout device.

NOTE—Such a device can be classed as either Class A or Class B depending on the class of the current-limiting fuse used.

cutout fuse support: A support that uses an insulator or insulators having a single-point mounting bracket, generally located centrally between the terminals that are mounted at each end of the insulator(s).

design tests; type tests: Those tests made to determine the adequacy of a particular type, style, or model of equipment with its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions if specified.

disconnecting cutout: A type of disconnecting switch, created by using a disconnecting blade in a cutout fuse support, used for changing the connections in a circuit or for isolating purposes. *See also:* **switch**.

NOTE—A disconnecting cutout is required to carry load current continuously and also abnormal or short-circuit currents for short intervals as specified. These devices have no load-break ability if they are not equipped with a load-breaking means.

disconnecting switch: A switch, created by using a disconnecting blade in a fuse support, used for changing the connections in a circuit or for isolating purposes. *See also:* **switch**.

NOTE—A disconnecting switch is required to carry load current continuously and also abnormal or short-circuit currents for short intervals as specified. These devices have no load-break ability if they are not equipped with a load-breaking means.

distribution class; distribution class fuse: *See:* **fuse classification, Class A**.

dropout fuse: A fuse in which the fuseholder or fuse unit automatically drops into an open position after the fuse has interrupted the circuit.

exhaust-control device: An attachment that, when added to a vented fuse, confines and condenses the gasses developed during circuit interruption, and consequently, substantially reduces the venting of the fuse.

NOTE—{muffler} See 1.4.2.

expendable cap (of an expendable-cap cutout): A replacement part or assembly for clamping the button head of a fuse link and closing one end of the fuseholder. It includes a pressure-responsive section that opens to relieve the pressure within the fuseholder when a predetermined value is exceeded during circuit interruption.

expendable-cap cutout: An open cutout having a fuse support designed for, and equipped with, a fuseholder having an expendable cap.

expulsion fuse: A device which, when the fuse element melts, accomplishes current interruption aided by the expulsion (ejection) of gasses that are produced by the arc interacting with certain fuse components. An expulsion fuse interrupts the current in the circuit close to the circuit's normal current zero.

NOTE—There are two classes of expulsion fuses, Class A and Class B.

external capacitor fuse: A fuse external to, and in series with, a capacitor unit or group of capacitor units.

full-range current-limiting fuse: *See: current-limiting fuse.*

fuse; fuse unit: A current-carrying protective device that, when heated by a particular current for sufficient time, will melt ("fuse") one or more of its fuse elements. Upon fuse element melting, a current-carrying arc interacts with fuse components to produce current interruption, to open the circuit, and to withstand the recovery voltage.

NOTE 1—A fuse comprises all the parts that form a device capable of performing the prescribed functions. It might or might not be the complete device that is necessary to connect into an electrical circuit.

NOTE 2—Fuses that use a replaceable fuse link require that the fuse link be assembled into the fuseholder, so it is then a current-carrying and interrupting device.

NOTE 3—A fuse unit is a fuse plus any additional reusable parts required for it to connect to a fuse support or into the electrical circuit.

fuse classification: Fuses are specified as Class A or Class B, indicating where in a power system they are likely suitable for use; testing requirements reflect this, with different specifications for the two classes primarily related to transient recovery voltage (TRV) and X/R .

NOTE 1—Class A fuses were called "Distribution Class" and Class B fuses were called "Power Class" in IEEE fuse standards published prior to the 2016 revision of IEEE Std C37.41.

NOTE 2—See 5.1 and IEEE Std C37.48 for more information on fuse classes.

fuse-container; canister: A close-fitting container that supports the fuse or fuse unit and restricts the air, gas, or liquid flow surrounding the fuse.

NOTE—The abbreviation F/C is used for a fuse and container/canister combination.

fuse disconnecting switch: A disconnecting switch in which a fuse unit, or fuseholder with a fuse link, form all or part of the blade. *See also: cutout; disconnecting switch.*

NOTE—{disconnecting fuse} See 1.4.2.

fuse element: The part(s) of a fuse designed so that melting occurs here first when the current exceeds a definite current for a definite period of time.

NOTE—The fuse element can consist of more than one functional part in series, with different parts designed to respond to different currents. Fuse elements can also be used in parallel. In addition, some designs use a parallel element to the “main” element(s) to trigger an indicator or striker, or, in the case of expulsion fuses, use a parallel wire (“strain element”) to reduce tension forces on the fuse element. Thus, for example, fuse standards could refer to “current-limiting element,” “expulsion element,” and “striker element,” all within the same fuse. It should be noted that for some designs, at a particular current, not all parts participate in the interruption process. In some cases, this leads to special testing requirements, depending on the fuse design.

fuse-enclosure package (FEP): An enclosure supplied with one or more fuses as a complete package where the application data covering the specific fuse(s) and enclosure is available. *See also:* **fuse-container; canister.**

NOTE 1— Depending on the application, the fuse(s) also might or might not be mounted in a fuse-container that is then assembled into the enclosure. See 1.5.

NOTE 2— When the fuse is mounted directly inside an enclosure, it has relatively free air, gas, or liquid flow surrounding the fuse. A fuse-container restricts the flow of the medium immediately surrounding the fuse. See 1.5.

fuse link: The part of an expulsion fuse that contains the fusible element, and so forth, intended to be replaced after the fuse has operated. The fuse link has a flexible leader, and a gas-evolving tube surrounding the fuse element (auxiliary tube) to provide for the expulsion action at low currents.

fuse support: An assembly that consists of the mounting means, insulator(s), fuse support contacts, and required parts and terminals for connecting the device into the circuit. *See also:* **cutout fuse support.**

NOTE 1—There are a large variety of fuse support styles designed to meet various user requirements. Some common types are discussed and illustrated in IEEE Std C37.48.

NOTE 2— {fuse-base; fuse-mount}; see 1.4.2.

fuse support contacts: The current-carrying parts of a fuse support that engage the contacts of the fuseholder, fuse unit, or disconnecting blade.

NOTE—{contact clips; fuse-base contacts; fuse clips}; see 1.4.2.

fuse unit: *See:* **fuse; fuse unit.**

fuseholder: An expulsion fuse assembly that provides a means of making contact between the fuse link or refill unit and the contacts or clips of the fuse support.

general-purpose current-limiting fuse: *See:* **current-limiting fuse.**

homogeneous series (of fuses, fuse units, or refill units): A homogeneous series is a group of fuses that have prescribed similarities. A complete range of fuses may be organized into one or more homogeneous series, such that the testing of a reduced number of fuses will qualify all of the fuses in that series.

NOTE 1—For any particular test, more than one homogeneous series can be required to represent the total range of available current ratings of these devices.

NOTE 2—The homogeneous series for one particular test can be different from the homogeneous series for another particular test.

NOTE 3—It should be noted that in some cases a “homogeneous series” may contain only one current rating.

housing (of a composite polymeric insulator): The outer insulating part(s) that provides the necessary leakage distance and other dielectric characteristics of the insulator.

indicating fuse: A fuse that automatically provides an indication that the fuse has operated.

indicator (of a fuse): A device that is a part of some types of fuses, fuse units, or refill units that operates when the fuse is clearing the circuit. This device provides an indication that this particular fuse has operated.

I^2t : The integral of the square of the current during a given time interval in ampere-squared-seconds (A^2s), as shown in the following equation:

$$I^2t = \int i^2 dt \quad A^2s$$

NOTE—The melting I^2t is equal to the integral of the square of the current during the melting time of the fuse; the clearing I^2t is equal to the integral of the square of the current during the clearing time of the fuse; the clearing time is equal to the sum of the melting time and arcing time; the I^2t (ampere-squared-seconds) multiplied by the resistance (ohms) through which the current flows is equal to the energy (joules) that will be produced in the resistance.

insulator trunk: The central insulating part of an insulator from which the sheds project.

insulator unit; insulator body: An insulator that is assembled with metal parts or other means so that it can be attached to other insulating units or to the parts of the device that might have different voltages or a ground potential.

K factor: A factor (less than unity) that when multiplied by a current on the minimum melting time-current-characteristic of a fuse produces a point (at the same time value) on an overload characteristic for that fuse.

link-break cutout: A fuse cutout that is a load-break cutout operated by mechanically breaking the fuse link element to initiate a normal cutout interrupting operation. *See: cutout. See also: expulsion fuse.*

liquid fuse; liquid fuse unit: A fuse in which the arc is drawn through a liquid.

liquid-immersible current-limiting fuse/fuse unit: A current-limiting fuse or fuse unit suitable for applications that require total or partial immersion in oil or other dielectric liquid.

NOTE—The fuse is normally immersed in a liquid-filled enclosure, the liquid of a transformer, or an enclosure containing switchgear.

live parts: Those parts that are designed to operate at a voltage different from that of the ground.

maximum enclosure current (I_{sep}); maximum permissible continuous current (I_{encl}): The designated value of constant rms current in amperes, at rated frequency, assigned to a device by the manufacturer at a specified ambient temperature higher than 40 °C. *See also: allowable continuous current; rated current.*

NOTE—By agreement between the manufacturer and user, maximum component temperatures may be higher than those specified for ambient temperatures up to 40 °C.

melting time (of a fuse): The time that elapses from the initiation of a current that will melt the fuse element to the initiation of arcing.

NOTE—{pre-arcing time (of a fuse)}; see 1.4.2.

minimum melting current: The lowest current that will melt the fuse element at a specified time and under specified conditions.

NOTE—The minimum melting time-current-characteristic curve for a fuse is generally derived with the fuse at an ambient temperature of 20 °C to 30 °C. An exception to this can be for fuses used where very high ambient temperatures exist.

mounting position (of a switch or fuse): A position determined by, and corresponding to, the approximate position of the switch blades, fuseholder, or fuse unit of the device relative to the surface of the earth.

NOTE—The usual positions are as follows:

- a) Vertical
- b) Horizontal upright (when the switch blade, fuseholder, or fuse unit is mounted above the supporting insulators)
- c) Horizontal underhung (when the switch blade, fuseholder, or fuse unit is mounted below the supporting insulators)
- d) Angle (from vertical) (common angles for these devices range from 15° to 30° from the vertical)

peak let-through current (of a current-limiting fuse): The highest instantaneous current passed by the fuse during its circuit-interrupting process.

NOTE—{cutoff current (of a current-limiting fuse)}; see 1.4.2.

peak let-through current characteristic curve (of a current-limiting fuse): A curve showing the relationship between the maximum peak current that can be passed by a fuse during interruption and the rms prospective current of the circuit, under specified circuit conditions.

NOTE—{cutoff current characteristic curve (of a current-limiting fuse)}; see 1.4.2.

peak overvoltage (for current-limiting fuses): The highest instantaneous peak value of the voltage that can exist across a current-limiting fuse during its arcing time.

polymeric insulator: An insulator whose body consists of non-ceramic-based material.

power: A general term used by reason of specific electrical characteristics to denote restriction of the modified term to voltages and frequencies used to distribute electrical energy.

power class: *See: fuse classification, Class B.*

power fuse; power class fuse: *See: fuse classification, Class B. See also: power.*

power-frequency dew withstand voltage: The rms voltage that can be applied to an insulator or a device, completely covered with condensed moisture, under specified conditions for a specified time, without causing flashover or puncture of any solid dielectric material.

power-frequency dry-withstand voltage: The rms voltage that can be applied to a dry insulator or device under specified conditions for a specified time without causing flashover or puncture of any solid dielectric material.

power-frequency recovery voltage: The power-frequency rms voltage that occurs across the terminals of a pole of an alternating current circuit-interrupting device after the interruption of the current and after the high-frequency transients have subsided.

power-frequency wet-withstand voltage: The rms voltage that can be applied to a wetted insulator or device under specified conditions for a specified time without causing flashover or puncture of any solid dielectric material.

pre-arcing time (of a fuse): *See: melting time (of a fuse).*

prospective current (of a circuit and with respect to a fuse): Current that would flow in the circuit if the fuse were replaced by a conductor of negligible impedance.

NOTE 1—This value is specified preferably in rms symmetrical amperes; however, for special conditions, it might be specified as asymmetrical or as peak amperes.

NOTE 2—{available short-circuit current (at the point of test)}; see 1.4.2.

prospective fault current: Current that could flow in a circuit (and through a fuse) if a fault, having a negligible impedance, were to occur at a particular point in the circuit.

NOTE—This current is usually compared to the rated maximum interrupting current or the time-current characteristics of a fuse, fuses, or other coordinating devices when application requirements are considered.

prospective interrupting current: Prospective current evaluated at a time corresponding to the instant of the initiation of the interrupting process.

NOTE—For fuses, this instant is usually defined as the moment of the initiation of the arc during the interrupting process.

puncture (of an insulator): The permanent loss of dielectric strength due to disruptive discharge passing through the solid insulating material of an insulator.

NOTE—While the puncture of an insulator during a dielectric test normally represents a failure, there are certain tests on devices using polymeric insulators for which, depending on the location of the puncture, a puncture does not represent a failure. Such exceptions are defined as part of the test.

radio-influence tests: Tests that consist of the application of voltage and the measurement of the corresponding radio-influence voltage produced by the device being tested.

rated continuous current: *See: rated current.*

rated current, (I_r): The designated value of constant rms current in amperes, at rated frequency, assigned to a device by the manufacturer at a maximum ambient temperature of 40 °C, and based on maximum component temperature rises.

NOTE 1—The current that a device is capable of carrying continuously in a given set of circumstances can be higher or lower than the assigned “rated current.” *See also: allowable continuous current (I_a); maximum enclosure current (I_{sep}).*

NOTE 2—The rated current, I_r , of a device is used to specify various test requirements.

rated capacitor discharge energy, Joule rating: The stored energy in a capacitor that a fuse has been shown to be capable of withstanding during a capacitor discharge breaking test, as shown in the following equation:

$$E = \frac{CV_i^2}{2}$$

where

E is energy in joules
 C is the capacitance in microfarads
 V_i is the instantaneous voltage in kilovolts

rated maximum capacitive interrupting current: The maximum capacitive interrupting current that the fuse is capable of breaking under the conditions of use and behavior prescribed in this standard.

rated lightning impulse withstand voltage: The designated maximum peak withstand-voltage value, of a lightning impulse voltage wave, that is assigned to the device regarding its ability to withstand a lightning impulse voltage without causing flashover or puncture or disruptive discharge of any non-restoring dielectric material. *See: basic impulse insulation level (BIL).*

NOTE—An impulse is an intentionally-applied aperiodic transient voltage wave that usually rises rapidly to a peak value and then falls more slowly to zero.

rated maximum application temperature (RMAT): The maximum ambient temperature at which a device is suitable for use without causing any deterioration that would inhibit its ability to interrupt the circuit.

NOTE 1—A fuse might not be suitable for normal continuous operation at its rated maximum application temperature as this surrounding temperature in some applications might only exist under abnormal conditions such as overload or equipment failure conditions. For these applications, the fuse would not be assigned an allowable continuous current at its rated maximum application temperature. It would be assigned this current rating at a lower temperature where the fuse would be expected to operate continuously. Manufacturers should provide the users of fuses that cannot operate continuously at their rated maximum applications temperature with the proper information that indicates the conditions under which the fuse may be used continuously.

NOTE 2—Fuses that are applied at temperatures that exceed their rated maximum application temperature might not interrupt the circuit when called upon to perform that function.

NOTE 3—{rated maximum reference ambient temperature, maximum application temperature}; see 1.4.2.

rated maximum interrupting current: The designated maximum value in rms amperes that is assigned to a device regarding its interrupting ability. When tested as specified, the device is capable of successfully interrupting a power system circuit that can produce this current. These ratings are normally provided in rms symmetrical amperes and specified circuit conditions.

NOTE 1—This value is the maximum value of current that the device is capable of interrupting and should not be exceeded without consulting the manufacturer.

NOTE 2—{rated maximum breaking current; rated interrupting capacity}; see 1.4.2.

rated maximum voltage, (V) (U_r): The designated maximum value in rms volts that is assigned to the device regarding its ability to operate continuously at this assigned voltage. This voltage is used in many of the tests required for the device.

NOTE 1—This value is the maximum value of voltage for which the device is capable of being applied and should not be exceeded without consulting the manufacturer.

NOTE 2—{maximum voltage rating}; see 1.4.2.

rated minimum interrupting current: The designated minimum value in rms amperes that is assigned to the device regarding its low current-interrupting capability. When tested as specified, the device is capable of successfully interrupting a power system circuit that can produce this current level. These ratings are normally provided in rms symmetrical amperes and specified circuit conditions.

NOTE—This value is the minimum value of current that the device is capable of interrupting and the device should not be applied where the prospective fault current could be lower for a time sufficient to melt the fuse, without consulting the manufacturer.

rated power frequency: The frequency of the power system at which the device has been designed to operate during its normal operation.

NOTE 1—Except as allowed for in this standard, devices designed for a particular frequency should not be used at other frequencies without consulting the manufacturer.

NOTE 2—{rated frequency}; see 1.4.2.

rating; rated: A qualifying term that when applied to an operating characteristic indicates the designated limit(s) of the characteristic for application under specific conditions.

NOTE—Typical uses are for characteristics such as maximum voltage, current, maximum and minimum interrupting current, frequency, and other operating characteristics.

recovery voltage: The voltage that occurs across the terminals of a pole of a circuit-interrupting device after the interruption of the current. A recovery voltage usually consists of a power-frequency recovery voltage that is sometimes modified by high-frequency transient voltages.

refill unit (of a fuseholder): An assembly comprising the fuse element, the items that facilitate current interruption, and the remaining parts requiring replacement after each fuse's circuit-interrupting operation so that the fuseholder is restored to its original operating condition. A *refill unit* is different from a *fuse unit* in that it requires the use of a fuseholder. *See also:* **fuse; fuse unit.**

resin polymeric insulator: A polymeric insulator whose body is made from only one insulating part and which is equipped with end fittings.

routine tests: Those tests made to check the quality and uniformity of the workmanship and materials used in the manufacture of switchgear or its components.

strain element (of a fuse): In order to relieve the current-responsive element of the tensile strain that can be imposed on it, some fuses use a high-resistance wire or other part in parallel with it. During the interrupting process, the fusible portion of the current-responsive fuse element melts first, the strain element melts next, and then arcing commences. This parallel strain element might be a factor in the total melting characteristics of the fuse. This effect is more predominant in the smaller ratings of these types of fuses.

NOTE—{strain wire (of a fuse)}; see 1.4.2.

striker (of a current-limiting fuse): A device that is a part of some current-limiting fuses, fuse units, or refill units that operates when the fuse is clearing the circuit. This device releases a stored energy that can be used to cause operation of other apparatus, provide an interlock to other apparatus, and/or provide other means to indicate that this particular current-limiting fuse has operated.

surge-resistant fuse link: A fuse link that has been subjected to a specified lightning surge resistant test and demonstrated that it can withstand such a surge without damage.

switch: A device that is designed with a switch blade that is used for closing, opening, or changing the connections in a circuit or system. It can also be used for isolation purposes. *See also:* **disconnecting cutout; disconnecting switch.**

NOTE—A switch is required to carry load current continuously and also abnormal or short-circuit currents for short intervals as specified. These devices have no load-break ability if they are not equipped with a load-breaking means.

switch stick: An electrically insulating stick or pole with a head or hook. Its primary functions are opening or closing fuses and switches or inserting and removing the fuseholder, fuse unit, and disconnecting blade from the device's support. This stick is generally used for distribution equipment that has a means for utilizing this device.

NOTE 1—See Annex H for description.

NOTE 2—{fuse hook; hot stick; switch hook}; see 1.4.2.

temperature-rise tests: Tests to determine the temperature rise, above ambient, of various parts of the tested device when subjected to specified test quantities.

NOTE 1—The test quantities can be rated current, allowable continuous current, and so forth.

NOTE 2—Values for various types of devices are shown in Table 7.

terminal: A device used for attaching an electrical conductor to apparatus in order to connect the apparatus into the electrical system. The electrical conductor is typically a wire or other similar conducting material.

NOTE—{connector}; see 1.4.2.

time-current-characteristic (TCC): The correlated values of time and current that designate the performance of all or a stated portion of the functions of the fuse. The time-current-characteristics for fuses are generally presented as a curve. The most useful curves plot the minimum melting time and maximum (total) clearing time versus current. For some applications, average melting and maximum melting data can also be useful.

time-current tests: Tests that consist of the application of current to determine the relation between the rms alternating current and the time for the fuse to perform the whole or some specified part of its interrupting function.

transient recovery voltage (TRV): The voltage transient that occurs across the terminals of a circuit-interrupting device after interruption of the current has occurred.

NOTE—The voltage magnitude is the voltage as compared to ground. The term can be used for describing the transient recovery voltage (TRV) as an inherent circuit TRV, a modified circuit inherent TRV, or an actual TRV. The inherent circuit TRV is the transient that would occur at that point in the circuit if a perfect interrupter were interrupting the circuit at that point. Low-arc-voltage interrupters, such as vacuum devices, are very close to perfect interrupters. For test purposes, a special device is used to determine inherent circuit TRV. Many devices will modify the voltage magnitude, the frequency, or both so that a modified circuit inherent TRV occurs. An actual TRV is the transient that is measured when a specific interrupting device operates and clears the circuit.

type tests: *See: design tests.*

vent (of a fuse): The means provided for the escape of the gases or other arc products developed during circuit interruption.

vented fuse; vented fuse unit: A fuse with provision for the escape of arc gases, or solid particles, or other arc products to the surrounding atmosphere during circuit interruption.

4. Normal (usual) and special (unusual) service conditions

4.1 General

The capabilities, as defined in this standard, for fuses and other devices is predicated on the device being used and applied in accordance with the manufacturer's recommendations and under circuit conditions that are equal to, or less severe than, the conditions required by the specification and testing standard for the device. The environment where the fuse is used can affect its performance and shall be carefully considered for all applications. Devices covered by this standard should not be closed into an energized circuit since they do not have making-current ability and devices that do not have load-breaking means should not be opened with the circuit energized. However, if load-breaking means are provided by the manufacturer and tested to applicable load-break standards, the device will still meet the requirements of this standard provided all requirements are met with the load-break means in place.

4.2 Normal service conditions

4.2.1 For fuses and switches rated for use at a maximum application temperature of 40 °C

Equipment conforming to this standard that is rated for use in a maximum application temperature of 40 °C or less shall be suitable for operation at its assigned ratings, providing the ambient temperature of the surrounding medium is not above 40 °C or below –30 °C, the altitude does not exceed 1000 m, and the frequency of the power system is 50 Hz or 60 Hz.

4.2.2 For fuses and switches rated for use at a maximum application temperature above 40 °C

Equipment conforming to this standard that is rated for use in a maximum application temperature of greater than 40 °C shall be suitable for operation at its assigned ratings, providing the ambient temperature of the surrounding medium is not above its assigned maximum application temperature and it is not below –30 °C, the altitude does not exceed 1000 m, and the frequency of the power system is 50 Hz or 60 Hz.

4.3 Special service conditions

The majority of fuses presently manufactured conform to the service conditions listed in 4.2. Fuses can be designed for other service conditions and still conform to this document, providing they are designed and tested with those other conditions considered in the design and testing process. Fuses are routinely designed for higher altitudes and power frequencies that are different than 50 Hz or 60 Hz. Applications with conditions other than those listed in 4.2 should be brought to the attention of those responsible for the design and application. The following is a listing of some of the conditions that fuses have in the past been designed to accommodate:

- a) Altitudes in excess of 1000 m; see 4.4
- b) Power system frequencies other than 50 Hz or 60 Hz
- c) Ambient temperatures less than –30 °C
- d) Exposure to damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture, or dripping water
- e) Exposure to abnormal vibration, shocks, or tilting
- f) Exposure to abnormal transportation or storage conditions
- g) Abnormal space limitations
- h) Abnormal operating duty, frequency of operation, difficulty of maintenance, and so forth

4.4 Altitude

The basis of rating for switchgear is standard reference atmosphere, commonly known as *sea level conditions*. Equipment covered by this standard that depends on air at atmospheric pressure for its insulating and cooling medium will have a higher temperature rise and a lower dielectric withstand when operated at altitudes above sea level. Historically, equipment covered by this standard has been successfully applied at altitudes up to 1000 m without the use of an altitude correction factor.

For installations at an altitude higher than 1000 m, the required insulation withstand level of external insulation at the service location shall be determined by multiplying the rated insulation levels at sea level by an altitude correction factor, K_a (> 1), while the dielectric withstand of a device at a particular altitude can be determined by multiplying its normal withstand by $1/K_a$. The rated current or allowable continuous current of the device might be reduced by another factor related to altitude, K_{ai} (< 1). Alternatively, a device can be used at its normal rated current and/or allowable continuous current provided that the ambient temperature does not exceed the rated ambient temperature multiplied by another factor related to altitude, K_{aa} (< 1). Table 1 gives the altitude correction factors for currents and temperatures, K_{ai} and K_{aa} , and also the historical altitude

correction factor, $1/K_a$, for dielectric strength, which has appeared in earlier IEEE fuse standards and is used in IEC 60282-1 [B6]. For the currently used switchgear altitude correction factors K_a , see Figure 1 of IEEE Std C37.100.1-2018.

Table 1—Altitude correction factors

Altitude above sea level		Altitude correction factor to be applied		
		Rated current ^a	Ambient temperature ^a	Dielectric strength
Meters	Feet	K_{ai}	K_{aa}	$1/K_a$
1000	3300	1.00	1.00	1.00
1200	4000	0.99	0.992	0.98
1500	5000	0.99	0.980	0.95
1800	6000	0.98	0.968	0.92
2100	7000	0.98	0.956	0.89
2400	8000	0.97	0.944	0.86
2700	9000	0.96	0.932	0.83
3000	10 000	0.96	0.920	0.80
3600	12 000	0.95	0.896	0.75
4300	14 000	0.93	0.872	0.70
4900	16 000	0.92	0.848	0.65
5500	18 000	0.91	0.824	0.61
6100	20 000	0.90	0.800	0.56

^aUse one correction factor, K_{ai} or K_{aa} , but not both, for any one application. If the derating, as determined from the table, is significant, equipment of suitable higher rating should be chosen to meet requirements after the correction factor has been applied.

5. Classifications, ratings, and characteristics

5.1 Classifications

Testing requirements are specified for two classes of expulsion and current-limiting fuses. The class is defined according to the ability of the fuse to comply with transient recovery voltage (TRV), X/R (power factor), and certain interrupting test requirements. They are termed Class A {distribution class} and Class B {power class}. In most cases, the two classes have separate tables (e.g., Table 15 gives TRV values for Class A expulsion fuses while Table 18 gives TRV values for Class B expulsion fuses), but in other cases, a single table contains separate requirements for each class (e.g., Table 21 for interrupting tests for current-limiting fuses).

In general, Class A devices are intended for use in locations more remote from major substations than Class B devices. Thus, testing for Class A devices generally has specified TRV conditions characterized by lower values of peak voltage and rate of rise of recovery voltage than those for Class B fuses. Also, Class B devices generally have X/R values specified as higher than for Class A devices.

5.2 Ratings

5.2.1 General

The following ratings are covered, with additional information located as indicated:

- a) Ratings of a fuse support:
 - 1) Rated maximum voltage, (V) (U_r); see 5.2.2
 - 2) Rated current, I_r ; see 5.2.3.2
 - 3) Rated lightning impulse withstand voltage; see 5.2.11
 - 4) Rated power-frequency withstand voltage; see 5.2.12
- b) Ratings of a fuse:
 - 1) Rated maximum voltage, (V) (U_r); see 5.2.2
 - 2) Rated current, I_r ; 5.2.3.3
 - 3) Rated maximum interrupting current; see 5.2.6
 - 4) Rated minimum interrupting current (for backup current-limiting fuses and capacitor fuses); see 5.2.7
 - 5) Rated frequency; see 5.2.8
 - 6) Rated capacitor discharge energy (for capacitor fuses); see 5.2.9
 - 7) Rated maximum application temperature (for devices intended for use in surrounding temperatures above 40 °C); see 5.2.10
- c) Additional ratings of a disconnecting device
 - 1) Rated short-time withstand currents of a disconnecting switch; see A.7
 - 2) Load-breaking current (for devices fitted a load-breaking means); see A.8

5.2.2 Rated maximum voltage, (V) (U_r)

5.2.2.1 Fuse links

Fuse links do not have a voltage rating independent of a specific device. The fuse link might be voltage sensitive, however it is the combination of the fuseholder and fuse link that is required to operate properly from the lowest current that melts its element to the maximum interrupting rating of the combination device. Fuse links are tested with a specific voltage rated device and the combination is given a maximum voltage rating by the manufacturer. When applying a fuse link in a device from a different manufacturer than was tested or different rating, proper operation cannot be assumed.

5.2.2.2 Class A and Class B fuses

Rated maximum voltage is that used in the designation of the fuse or fuse support, and certain other fuse component parts, from which the test conditions are determined.

It is preferred that the rated maximum voltage of a fuse or fuse support be selected from the voltages given in Table 2.

Table 2— Preferred values of rated maximum voltage, (V) (U_r)

Rated maximum voltage (kV)	
Class A fuses	Class B fuses
2.8	2.8
5.5	5.5
8.3	8.3
15.5	15.5
17.2	17.2
23.0	23.0
27.0	27.0
38.0	38.0
—	48.3
—	72.5
—	121.0
—	145.0
—	170.0

5.2.2.3 Capacitor fuses

The preferred rated maximum voltages for capacitor fuses shall be as in Table 2. These ratings apply primarily to line fuses, since unit fuses are often designed specifically for a particular capacitor bank. Additional information regarding rated maximum voltage for all capacitor fuses is specified as follows:

- The rated voltage (V) of a fuse is its rated maximum voltage, that is, the maximum power frequency voltage to which it may be subjected.
- When a fuse is subjected to power-frequency capacitive currents, it shall be capable of operating continuously at a voltage of V and then withstand this voltage plus any dc voltage component that results from any capacitive charge trapped on the capacitor or capacitor bank after the fuse melts and subsequently clears the circuit.
- The fuse rated maximum voltage is based on proper fuse operation at the maximum continuous system operating voltage. It does not include provision for operation during transient or short-time overvoltage conditions associated with restriking circuit breakers, system faults, and so forth.
- A fuse shall be capable of disconnecting a faulty capacitor unit at the maximum peak voltages specified in Table 3.
- A fuse shall be capable of withstanding a peak recovery voltage, which is the fundamental frequency voltage appearing across the blown fuse during the first cycle after interrupting, including any dc component. This fuse peak recovery voltage capability shall be as specified in Table 3.

Table 3— Peak recovery voltages for capacitor fuses

Type of fuse	Maximum peak voltage (V) ^a	Peak recovery voltage (V)
Column 1	Column 2	Column 3
Non-current limiting	$1.0V\sqrt{2}$	$2.0V\sqrt{2}$
Current limiting	$2.0V\sqrt{2}$	$2.0V\sqrt{2}$

^a The values in column 2 are based on the voltages that normally can occur across the capacitor unit terminals. These values are transients of short duration, with a steady-state value of V.

5.2.3 Rated current

5.2.3.1 Fuses, fuse units, fuse links, and refill units

The preferred values of rated current for Class A and Class B fuses, fuse units, fuse links, and refill units shall be as shown in Table 4.

Table 4—Preferred values of rated current for fuses, fuses units, fuse links, and refill units

Rated current (A)								
0.5	1	2	3	5	6	7	8	10
12	15	18	20	25	30	40	50	65
80	100	125	140	150	200	250	300	400

5.2.3.2 Rated current of a fuse support (I_r)

This is the maximum current assigned to a fuse support that a new clean fuse support will carry continuously without deterioration and without exceeding specified temperature rises (5.3.2), when equipped with a fuse unit, fuseholder, and fuse link/fuse refill unit, or other current carrying device, of the same, or lower, current rating designed to be used in the particular fuse support, and connected to the circuit with certain specified conductor sizes and lengths, at an ambient air temperature of not more than 40 °C.

The preferred values of rated current for fuse supports shall be as shown in Table 5

Table 5—Preferred values of rated current for fuse supports

Rated current (A)					
10	25	50	100	200	300
400	450	600	720		

5.2.3.3 Rated current of a fuse or fuse unit (I_f)

This is the current assigned to a fuse or fuse unit that a new clean device will carry continuously without deterioration and without exceeding specified temperature rises (5.3.2) when mounted on a fuse support, or other mounting means, specified by the manufacturer, and connected to the circuit with certain specified conductor sizes and lengths, at an ambient temperature of not more than 40 °C.

5.2.3.4 Rated current of a fuseholder, a refill unit, or a fuse link (I_l)

This is the current assigned to a fuseholder, refill unit, or fuse link that a new device, assembled with other components specified by the manufacturer and needed to make up a complete fuse (including, if necessary, a fuse support), will carry continuously without deterioration and without exceeding specified temperature rises (5.3.2), at an ambient temperature of not more than 40 °C.

5.2.3.5 Rated current of a fuse-enclosure package (FEP)

This is the rated current assigned to a fuse-enclosure package that a new clean device will carry continuously without deterioration and without exceeding specified temperature rises (5.3.2), at an ambient temperature of not more than 40 °C. The relevant ambient temperature is that of the fluid specified for the rated maximum application temperature (RMAT) in 1.5.

5.2.4 Allowable continuous current rating of a device (I_a)

This is the current assigned to a device listed in 5.2.3.2, 5.2.3.3, 5.2.3.4, or 5.2.3.5 and using the conditions listed but at a specified ambient temperature. The device shall be capable of carrying this allowable continuous current continuously without deterioration and without exceeding the maximum value of temperature specified in 5.3.2 when it is in the normal service position. The ambient temperature may exceed 40 °C.

5.2.5 Maximum enclosure current (I_{rep}) {Maximum permissible continuous current (I_{encl})}

This is the maximum current a device listed in 1.1 is permitted to carry when the ambient temperature is higher than 40 °C. The device shall be capable of carrying this current continuously without deterioration. At certain (relatively high) ambient temperatures, or in certain enclosures, the maximum values of temperature given in 5.3.2 may be exceeded by agreement between the manufacturer and user.

5.2.6 Rated maximum interrupting {breaking} current

5.2.6.1 General

Rated maximum interrupting currents are designated by the manufacturer and the preferred values shall be selected from the R10 series of preferred numbers. The R10 series is comprised of the numbers 1, 1.25, 1.60, 2.00, 2.50, 3.15, 4.00, 5.00, 6.30, 8.00, and their multiples of 10.

5.2.6.2 Fuse links

Fuse links do not have a rated interrupting current since it is a characteristic of the combination of the fuse link and the device that was tested.

5.2.6.3 Capacitor fuses

Capacitor fuses have both an inductive and capacitive maximum interrupting current. The preferred rated maximum inductive interrupting currents of capacitor fuses are as listed in 5.2.6.1. The preferred rated maximum capacitive interrupting currents for capacitor fuses are 1 kA rms, 2.5 kA rms, 3.15 kA rms, 4 kA rms, and 5 kA rms. Other values shall be the subject of an agreement between manufacturer and user.

5.2.7 Rated minimum interrupting {breaking} current

5.2.7.1 Backup current-limiting fuses

The rated minimum interrupting current for backup current-limiting fuses shall be designated by the manufacturer.

5.2.7.2 Capacitor fuses

The rated minimum capacitive interrupting current for all types of capacitor fuses and the rated minimum inductive interrupting current for current-limiting backup capacitor fuses shall be designated by the manufacturer.

5.2.8 Rated frequency

Standard values of rated frequency are 50 Hz, 60 Hz, or both. It should be noted that fuses are typically tested at either 50 Hz or 60 Hz. In the case of current-limiting fuses, experience has shown that while the same fuse design tested at current that produces a current-limiting action and at both frequencies generally exhibits slightly higher peak currents at 60 Hz and slightly higher clearing I^2t values at 50 Hz, fuses successfully passing all testing at one frequency are suitable for use at the other frequency.

In the case of expulsion fuses, fuses tested at 50 Hz are generally suitable for use at 50 Hz or 60 Hz; however, fuses tested only at 60 Hz are only suitable for use at this value.

5.2.9 Rated capacitor discharge energy (joules) for the capacitor discharge interrupting tests

A rated capacitor discharge energy (joule rating) is assigned to a fuse based on the energy stored in a capacitor test bank prior to the time it is discharged through the fuse in the capacitor discharge interrupting {breaking} tests (see 9.5.5). Values should be selected from the R10 series with a minimum of 10 kJ. The preferred value for current-limiting fuses is 40 kJ. To assign an “unlimited” rated capacitor discharge energy see 9.5.5.2.

The preferred frequency for the capacitor discharge interrupting tests:

$$f = 0.8 V$$

where

f is in hertz (Hz)

V is the rated voltage of the fuse, in volts (V)

Presentation of data: The rated capacitor discharge energy for unit fuses shall be presented as the kilojoules of parallel energy the fuse is capable of interrupting. If the tests are made at a frequency and/or voltage different than that specified in 9.5.5, this data shall also be presented.

5.2.10 Rated maximum application temperature (RMAT)

The rated maximum application temperature (RMAT) is the maximum ambient temperature at which the device is suitable for use as designated by the manufacturer. The device shall be capable of withstanding this temperature without any deterioration that would inhibit its ability to properly interrupt the circuit. The minimum rating allowable is 40 °C. The rated maximum application temperature of the device in degrees Celsius (°C) should be selected from the R20 series of preferred numbers. The R20 series is comprised of the numbers 1, 1.12, 1.25, 1.40, 1.60, 1.80, 2.00, 2.24, 2.50, 2.80, 3.15, 3.55, 4.00, 4.50, 5.00, 5.60, 6.3, 7.10, 8.00, 9.00, and their multiples of 10. Preferred values are 40 °C, 71 °C, 112 °C, and 140 °C.

5.2.11 Rated lightning impulse withstand voltage {basic impulse insulation level (BIL)}

The preferred values of rated lightning impulse withstand voltage are a function of the class of the device, the rated maximum voltage, and whether the device is intended for application in an outdoor or indoor environment. Preferred values are given in Table 6. Testing requirements in Clause 8 that appear in tables giving the test values to be used, are each based on the class of device and its environment. Test values are specified by the device's rated lightning impulse withstand voltage, rather than its rated maximum voltage. This is because devices having a particular rated maximum voltage can be available with more than one rated lightning impulse withstand voltage capability.

Table 6—Preferred rated lightning impulse withstand voltages

Rated maximum voltage (kV, rms) ^a	Rated lightning impulse withstand voltage (kV peak)		
	Class A indoor and outdoor devices	Class B outdoor devices	Class B indoor devices
2.8	45	—	45
	60		
5.5	60	—	60
	75		
8.3	75	95	75
	95		
15.5	95	110	110
17.2	110		
23.0	125	150	150
27	150		
38	150	150	150
	200	200	200
48.3	—	250	—
72.5	—	350	—
121.0	—	550	—
145.0	—	650	—
170.0	—	750	—

^aSee 5.2.2.

5.2.12 Rated power-frequency withstand voltage

The preferred values of power-frequency withstand voltage for any device are given in Clause 8 and are based on the device's preferred rated lightning impulse withstand voltage from Table 6. Values are given for indoor and outdoor devices, with indoor devices having values listed for dry conditions and outdoor devices listed for both dry and wet conditions.

5.2.13 Rated load-break current

Devices covered by this standard are not inherently load-breaking devices unless fitted with a load-breaking means. The rated load-break current for devices equipped with a load-break means shall be a minimum of the rated current as specified for these devices in 5.2.3. Certain fuses equipped with a load-break means are capable of operating in excess of the rated current during periods of overloading. In this case, the load-break rating shall be the maximum current the specific device can carry without melting the fusible element of the maximum fuse link that can be used in the device. For these devices, the manufacturer should be consulted to assure the proper load-break rating is assigned. In addition to being assigned a rated maximum load-break current (for an inductive current), a device might be assigned a rated maximum capacitive load-break current.

5.2.14 Ratings other than preferred

Special circuit or environmental conditions can require devices with ratings that are different from the preferred values specified in 5.2.2 through 5.2.12. For these devices, the ratings shall be agreed upon by the user and the manufacturer, and additional testing might be required to validate that the device is suitable for the intended application.

5.3 Characteristics

5.3.1 General

The following are characteristics:

- a) Characteristics of current-limiting fuses are as follows:
 - 1) Temperature rise limits; see 5.3.2
 - 2) Class; see 5.1
 - 3) Time-current characteristics (minimum melting and maximum clearing); see Clause 12
 - 4) Maximum arc voltage; see 9.3.8
 - 5) Peak let-through {Cut-off} current; see 9.3.9
 - 6) I^2t (minimum melting and maximum clearing); see 9.3.10
 - 7) K factor (for fuses intended for motor circuit applications); see Clause 17
- b) Characteristics of expulsion fuses are as follows:
 - 1) Temperature rise limits; see 5.3.2
 - 2) Class; see 5.1
 - 3) Time-current characteristics; see Clause 12

5.3.2 Maximum temperature and temperature rise limits

Devices shall be able to carry their rated current continuously without deterioration and without exceeding the limits of maximum temperature and temperature rise given in Table 7 when in their normal service position. Devices shall be capable of carrying an allowable continuous current without deterioration and without exceeding the maximum value of temperature specified in Table 7, when in a specified ambient temperature and in their normal service position (except see 5.2.5).

Table 7—Limits of temperature and temperature rise for components and materials where the rated maximum application temperature for the device is 40 °C or less

Component or material ^{a, b}	Maximum value of	
	Temperature °C	Temperature rise K
a) Contacts in air or other insulating gasses		
1) Spring-loaded contacts (copper or copper alloy)		
i) Bare	75	35
ii) Tin coated	95	55
iii) Silver or nickel coated	105	65
iv) Other coatings ^a	—	—
2) Bolted contacts or equivalent (copper, copper alloy, and aluminum alloy)		
i) Bare	90	50
ii) Tin coated	105	65
iii) Silver or nickel coated	115	75
iv) Other coatings ^a	—	—
b) Contacts in liquid insulating material (copper or copper alloy)		
1) Spring-loaded contacts		
i) Bare	80	40
ii) Silver, tin, or nickel coated	90	50
iii) Other coatings ^a	—	—
2) Bolted contacts		
i) Bare	100	60
ii) Silver, tin, or nickel coated	100	60
iii) Other coatings ^a	—	—
c) Bolted terminals in air ^c		
1) Bare	90	50
2) Silver, tin, or nickel coated	105	65
3) Other coatings ^a	—	—
d) Metal parts acting as springs ^d	—	—
e) Materials used as insulation and metal parts in contact with insulation of the following types:		
1) Bone fiber	70	30
2) Other insulating material ^e	—	—

^a If the manufacturer uses coatings other than those indicated in this table, the properties of these materials should be taken into consideration.

^b Where engaging contact surfaces have different coatings, the permissible temperatures and temperature rises shall be those of the component having the lowest values permitted.

^c The temperature of a terminal should be no higher than that of the nearest device contact also subject to temperature limits covered by this table.

^d The temperature or the temperature rise should not reach such a value that the elasticity of the metal is impaired.

^e Limited only by the requirements to not cause any damage to surrounding parts, and to be suitable for the temperatures anticipated, as determined by the device manufacturer.

5.4 Rating validation

5.4.1 Devices rated for use at a maximum application temperature of 40 °C or less

The tests required for the devices covered by this standard are summarized in Table 8. The ratings in this standard are validated as follows:

- a) Rated maximum voltage(s), validated by the dielectric and current interrupting {breaking} design tests specified in Clause 8 and Clause 9, respectively.
 - 1) For fuses that use a replaceable fuse link, fuse unit, or fuse refill, the rated maximum voltage of the device is validated by interrupting tests using the replaceable item.
 - 2) The replaceable item and the fuse shall be from the same manufacturer or as recommended by the manufacturer of the fuse. The rated maximum voltage is the highest voltage rating of the fuse where the specified replaceable item is capable of properly interrupting the circuit or aiding in the interruption process.
- b) Rated current, validated by the temperature-rise design tests at the rated current specified in Clause 11.
- c) Rated maximum and minimum interrupting {breaking} currents, validated by the current interrupting design tests specified in Clause 9. Minimum interrupting ratings apply only to backup current-limiting fuses. For certain fuse devices, the following ratings apply:
 - 1) For capacitor fuses, the rated capacitive interrupting current specified in 5.2.6.3 is validated by the current interrupting design tests at rated maximum voltage as specified in 9.5.4.
 - 2) For backup current-limiting fuses, the rated minimum interrupting current specified in 5.2.7.1 is validated by the current interrupting design tests specified in Clause 9. For capacitor fuses of this type, rated minimum capacitive interrupting currents are also specified and validated by testing in 9.5.
 - 3) While general-purpose current-limiting fuses may have a current below which they have not demonstrated an interruption capability, this potential application limitation is expressed in terms of a melting time limitation rather than a current limitation (i.e., general-purpose fuses have a demonstrated interrupting capability from their rated maximum interrupting current down to a current that causes melting in one hour).
- d) Rated lightning impulse withstand voltage {basic impulse insulation level (BIL)}, validated by the impulse withstand tests specified in Clause 8. These ratings apply only to devices that have a fuse support.
- e) Rated power frequency, as specified in 5.2.8 and validated by the design tests specified in Table 8.
- f) Rated load-break current (for devices equipped with load breaking provisions), validated by the design tests specified in A.8.

Current-limiting fuses (Class A and B) have three different subclasses that depend on the low current interrupting capability of the fuse. The three subclasses are backup current-limiting fuses, general-purpose current-limiting fuses, and full-range current-limiting fuses. Only backup current-limiting fuses have a rated minimum interrupting current. The other two types have low current capabilities as described in their definitions.

5.4.2 Devices rated for use at a maximum application temperature greater than 40 °C

For these devices with service conditions with a maximum application temperature above 40 °C, additional testing to validate the ratings of the device may be required and are subject to agreement between the user and manufacturer.

5.4.3 Devices rated for other service conditions

For devices and application with service conditions other than those specified in Clause 4, additional testing to validate the ratings of the device may be required and are subject to agreement between the user and manufacturer.

5.4.4 Fuse link ratings

Requirements specified in this standard cover the testing of a specific combination of a fuse link together with other components including a fuseholder, fuse support, and fuse disconnecting switch. The performance of other combinations cannot be implied from these tests.

6. Required design (type) tests

6.1 General

Design tests are performed to determine whether a particular design of fuse meets the characteristics specified and functions satisfactorily under normal conditions or under special specified conditions. Design tests are made on samples to check the specified characteristics of all fuses of the same type. These tests are not intended to be used as a part of normal production. The applicable portion (part) of these design tests may also be used to evaluate modifications of a previous design and to demonstrate that performance has not been adversely affected. Test data from previous similar designs can be used for current designs, where appropriate.

The clauses specifying the tests to be conducted upon completion of a new design or following a design change that affects performance are summarized in Table 8.

Table 8—Design (type) tests

Design test	Expulsion fuses	Current-limiting fuses	Expulsion and current-limiting fuses in fuse enclosure packages	Fuse supports for use with fuses and fuse disconnecting switches	Disconnecting devices created by the use of a removable fuse unit or switch blade	Expulsion, current-limiting, and combination types of external capacitor fuses	Fuse links used exclusively with expulsion fuses and fuse disconnecting switches	Fuses, fuse disconnecting switches and disconnecting devices with integral load-break
Dielectric ^a	8	8	8/8.6	8	8	8/8.7	—	—
Interrupting	9/9.2	9/9.3	9/9.4	—	—	9/9.5	—	—
Radio-influence	10	10	10	10	10	10	—	—
Temperature-rise	11	11	11/11.3	11	11	11	—	—
Time-current characteristics ^b	12	12	12	—	—	12	12	—
Manual-operation, thermal-cycle, and bolt-torque	13	13	13	13	13	13	—	—
Liquid-tightness ^c	—	—	14	—	—	—	—	—
Static-relief pressure tests for fuses that use expendable caps	15	—	—	—	—	—	—	—
Lightning surge impulse withstand	—	—	—	—	—	—	16	—
Withstand tests for motor circuit fuses	—	17	17	—	—	—	—	—
Special tests for cutouts utilizing polymeric insulators	18	—	18	18	18	18	—	18
Short-time withstand currents	—	—	—	—	A.7	—	—	—
Load-break	—	—	—	—	—	—	—	A.8

^a Required only on fuses and fuse units when they are mounted in a particular fuse support.

^b In the case of fuse cutouts, the TCC is almost wholly dependent on the link used, and so a fuse cutout without a link has no TCC and cannot be tested.

^c For current-limiting fuses and FEPs only (type 2CL and 3CL).

6.2 Requirements for re-testing modified devices

For devices covered by this standard, all applicable tests need not be performed on each design modification of a previously-tested design. To assure that overall performance has not been adversely affected as a result of the design modification, sufficient tests shall be performed to demonstrate that the modified design will have a performance that meets or exceeds the ratings and performance requirements specified in Clause 6. For devices that have been assigned ratings or performance requirements that are different from those specified in Clause 6, the modified design shall have ratings and performance requirements that meet or exceed the values assigned to the original device.

6.3 Parallel fuses

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 this standard, the testing of these fuses in parallel is subject to the homogeneous testing rules in 9.3.5.

6.4 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, or one imposing upon it more severe service conditions.

6.5 Fuses fitted with an exhaust-control device

Fuses fitted with an exhaust-control device shall be considered a separate design and be tested accordingly (see 9.4.1.6).

7. Common test requirements for all design tests

7.1 General

The requirements of Clause 7 apply to all tests in this standard unless alternative requirements are given in a specific clause or subclause.

7.2 Test values

7.2.1 Allowable tolerances

Testing parameters in this document 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.

7.2.2 Preferred values

In this standard the performance requirements and ratings represent normal requirements and preferred values. Special circuit or environmental conditions can require devices with performance and ratings that are different from those specified in these documents. For these devices, the user and the manufacturer shall agree upon the performance requirements and ratings.

7.3 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.

NOTE—Testing and provision of data for an FEP might have been the responsibility of the fuse manufacturer, but this requirement is intended to require that either the FEP supplier has performed appropriate testing, or that the fuse manufacturer is aware of the way in which their fuses are being used.

7.4 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 manufacturer's 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.

7.5 Test site conditions

7.5.1 Ambient temperature during test

The ambient temperature prevailing at the test site shall conform to the normal service conditions in accordance with 4.2.1 or 4.2.2.

7.5.2 Atmospheric conditions during test

Tests shall be conducted under atmospheric conditions prevailing at the time and place of the test. The barometric pressure and dry-bulb and wet-bulb thermometer readings shall be recorded so that applicable correction factors can be applied to the measurements. For system voltages below 72.5 kV, no humidity correction shall be applied (see 13.2.1.2 in IEEE Std 4™-2013).

7.6 Frequency and wave shape of test voltage

7.6.1 Frequency of test voltage

The frequency for all power-frequency tests shall be (50 ± 2) Hz or (60 ± 2) Hz.

7.6.2 Wave shape of test voltage

For all power-frequency tests, a sine wave of acceptable commercial standards shall be applied to the device. For the definition of the wave shape, see IEEE Std 4.

7.7 Devices to be tested

7.7.1 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.

7.7.2 Compatibility of components

Tests performed according to this standard shall utilize components made by the same manufacturer or as recommended for use by the manufacturer.

7.8 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 (however, see item b) below).
- b) An established phenomenon for expulsion fuses has been that the location of the lower test conductor relative to the fuseholder of a fuse or fuse cutout might, 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 fuse element and the lower fuseholder contact). While the manufacturer's recommendations for conductor placement relative to the tested device should be followed to reduce this phenomenon, it is nevertheless recognized that, on rare occasions, a fuse might interrupt current satisfactorily, but fail to drop open due to entanglement of the leader with some component of the device or test conductor. Providing that the leader has been fully ejected from the fuse tube during the interruption, the test may be considered "unsatisfactory" rather than a failure, and one of the following two procedures may be employed:
 - 1) Perform one additional test, using the same test conditions as the unsatisfactory test, using the same fuseholder and an identical fuse link.
 - 2) If the unsatisfactory test occurred during Table 14 Series 3, 4, or 5, repeat the entire test series. If the unsatisfactory test occurred during Series 1 or 2, repeat the entire half series (i.e., "min." or "max." ratings).

The test report shall report all of the tests performed, including the "unsatisfactory" test. Only one "unsatisfactory" test, involving failure to drop open, is acceptable during an entire group of tests as specified in Table 14.

- c) 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.
- d) Indicating fuses need not comply with any specific additional requirements other than that the indicator shall fully operate. If a 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 non-indicating fuse has met the requirements of the standard.
- e) 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 below), excluding a fuseholder, the condition of the device shall be as follows:

- f) Mechanical requirements: The condition of the device shall be in substantially the same condition as at the beginning of the test. It is acceptable for the bore of expulsion devices to have some amount of erosion.
- g) Electrical requirements: The device shall be capable of carrying rated current continuously at the rated maximum voltage. If there is evidence to suggest the device might not be able to carry rated current continuously because of contact deterioration, a temperature-rise test (see Clause 11) 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.
- h) Dielectric requirements: If there is evidence of insulator contamination from the test, a power-frequency dry-withstand test shall be performed at 80% of the normal test value specified for the device.

After certain groups of tests, as specified in Table 14 and Table 27, the fuseholder may be changed. The acceptance criteria f) through h) are to be met with the fuseholder that has just been tested, even though it might not be suitable for any additional testing.

NOTE—Examples of parts that are normally field replaceable include replaceable fuse links, fuse units, refill units, expendable caps, and exhaust-control devices. The device manufacturer will specify which parts are to be replaced after a test but note that the requirements of individual tests could limit the replacement of some parts until certain tests, or groups of tests, have been completed.

7.9 Test-conductor dimensions

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

Electrical connections shall be made by a 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 clauses in this standard 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 bare conductors, with sizes as specified in Table 9, unless the manufacturer specifies a different conductor size due to the typical application.

7.9.2 Dielectric and radio-influence test conductors

Electrical connections shall be made by a 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.

7.9.3 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 9. For fuses connected in parallel, the current rating to be considered is the total current assigned by the manufacturer.

Table 9—Size and length of bare conductors for specified tests

Rated current, I_r , of the device being tested (A)	Size of leads	Minimum length of bare copper leads	
		m	(in)
≤ 50	No. 6 AWG solid	1.2	(48)
$50 < I_r \leq 100$	No. 1 AWG stranded	1.2	(48)
$100 < I_r \leq 200$	No. 4/0 AWG stranded	1.2	(48)
$200 < I_r \leq 300$	250 kcmil	1.2	(48)
$300 < I_r \leq 400$	400 kcmil	1.2	(48)
$400 < I_r \leq 600$	600 kcmil	1.2	(48)

NOTE—Values in parenthesis are for information only.

7.10 Mounting and grounding of the device for tests

7.10.1 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 any anticipated current for the expected duration of current flow can be adequately carried. 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 7.10.2 through 7.10.6. Grounding is not required for temperature-rise tests (Clause 11) and time-current tests (Clause 12).

7.10.2 Fuses and fuse disconnecting switches

Fuses and fuse disconnecting switches shall be mounted on a rigid structure. The base shall be grounded.

7.10.3 Fuse cutouts

Fuse cutouts have traditionally been tested mounted on a wood crossarm that measures 9 cm × 11 cm (3 1/2 in × 4 1/2 in) in cross section. If an alternative arrangement is used (e.g., a more or less flexible mounting means), this shall be included in the test report. The device mounting bracket shall be grounded by a lead attached to the mounting bracket on the side of the crossarm opposite the device. See Annex G for mounting bracket details.

7.10.4 Fuses and fuse disconnecting switches used in FEPs

Fuses and fuse disconnecting switches used in FEPs shall be mounted in accordance with the FEP or fuse manufacturer's specifications. The enclosure and base of the device shall be grounded if applicable.

7.10.5 External fuses for shunt capacitors

7.10.5.1 Capacitor line fuses

Depending on the class and type of line capacitor fuse, it shall be mounted as specified in 7.10.2, 7.10.3, or 7.10.4.

7.10.5.2 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. The spacing between fuses shall be recorded.

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.

7.10.6 Multipole mounting

For multipole arrangements of fuses, and when the distance between poles is not fixed by their construction, it is necessary, for test purposes, to provide the minimum distance between poles as specified by the manufacturer.

8. Dielectric tests

8.1 Requirements common to all dielectric tests

8.1.1 General

Dielectric tests shall be conducted as specified in Clause 7 and Clause 8.

For all devices, the tests shall be made on three units equipped with any size fuse link or refill unit.

Dielectric tests are performed to determine the power-frequency dry and wet dielectric withstand voltages, and lightning impulse 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) and from terminals to parts that might 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.

A meaningful dielectric test can only be performed on a fuse or fuse unit in its mounting (fuse support). 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—is representative of 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.

The preferred dielectric test values are listed for Class A outdoor devices in Table 10, Class A indoor devices in Table 11, Class B outdoor devices in Table 12, and Class B indoor devices in Table 13. A device claiming a particular preferred value of rated lightning impulse withstand voltage shall be capable of withstanding the test voltages specified in the appropriate table, when tested as specified in Clause 8.

Class A and Class B indoor devices used in fuse enclosure packages (FEPs) shall be capable of withstanding the test voltages specified in Table 11 or Table 13 respectively, when tested as specified in Clause 8.

Table 10—Minimum dielectric withstand test voltages for Class A outdoor devices

Rated lightning impulse withstand voltage (kV peak) ^a	Minimum dielectric test voltages				
	Terminal-to-ground for all devices and pole-to-pole (phase-to-phase) for multi-pole devices			Terminal-to-terminal	
	Power-frequency dry-withstand test (kV, rms)	Power-frequency wet-withstand test (kV, rms) ^b	Impulse withstand test (kV, peak)	Power-frequency dry-withstand test (kV, rms)	Impulse withstand test (kV, peak)
45	15	13	45	15	45
60	21	20	60	21	60
75	27	24	75	27	75
95	35	30	95	35	95
110	35	30	110	35	110
125	42	36	125	42	125
150	70	60	150	70	150
200	95	80	200	95	200

^aSee 5.2.11.

^b Power-frequency wet withstand test voltages on the insulators that meet these values is satisfactory in lieu of this test, provided the design of the complete device does not decrease the power-frequency withstand test voltages of the insulators.

Table 11—Minimum dielectric withstand test voltages for Class A indoor devices

Rated lightning impulse withstand voltage (kV peak) ^a	Minimum dielectric test voltages				
	Terminal-to-ground for all devices and pole-to-pole (phase-to-phase) for multi-pole devices			Terminal-to-terminal	
	Power-frequency dry-withstand test (kV, rms)	Power-frequency dew-withstand test (kV, rms) ^{b,c,d}	Impulse withstand test (kV, peak)	Power-frequency dry-withstand test (kV, rms)	Impulse-withstand test (kV, peak)
45	15	10	45	15	45
60	19	15	60	19	60
75	26	24	75	26	75
95	35	26	95	35	95
110	35	26	110	35	110
125	42	28	125	42	125
150	60	40	150	60	150
200	95	80	200	95	200

^aSee 5.2.11.

^b Power-frequency dew withstand voltages on the insulators that meet these values is satisfactory in lieu of this test, provided the design of the complete device does not decrease the power-frequency withstand test voltages of the insulators.

^c When fuse enclosure packages use a liquid or a gas other than air for its dielectric medium, the dew test is not required.

^d When fuse enclosure packages use air for the dielectric medium, multipole devices require dew tests pole-to-pole only when there is a solid type insulation between the poles.

Table 12—Minimum dielectric withstand test voltages for Class B outdoor devices

Rated lightning impulse withstand voltage (kV peak) ^a	Minimum dielectric test voltages				
	Terminal-to-ground for all devices and pole-to-pole (phase-to-phase) for multi-pole devices			Terminal-to-terminal	
	Power-frequency dry-withstand test (kV, rms)	Power-frequency wet-withstand test (kV, rms) ^b	Impulse withstand test (kV, peak)	Power-frequency dry-withstand test (kV, rms)	Impulse withstand test (kV, peak) ^c
95	35	30	95	39	105
110	50	45	110	55	121
150	70	60	150	77	165
200	95	80	200	105	220
250	120	100	250	132	275
350	175	145	350	193	385
550	280	230	550	308	605
650	335	275	650	368	715
750	385	315	750	424	825

^aSee 5.2.11.

^bPower-frequency wet withstand test voltages on the insulators that meet these values is satisfactory in lieu of this test, provided the design of the complete device does not decrease the power-frequency withstand test voltages of the insulators.

^cSee 19.2.1.

Table 13—Minimum dielectric withstand test voltages for Class B indoor devices

Rated lightning impulse withstand voltage (kV peak) ^a	Minimum dielectric test voltages				
	Terminal-to-ground for all devices and pole-to-pole (phase-to-phase) for multi-pole devices			Terminal-to-terminal	
	Power-frequency dry-withstand test (kV, rms)	Power-frequency dew-withstand test (kV, rms) ^{b,c,d}	Impulse withstand test (kV, peak)	Power-frequency dry-withstand test (kV, rms)	Impulse withstand test (kV, peak)
45	15	10	45	17	50
60	19	15	60	21	66
75	26	24	75	29	83
110	50	30	110	55	121
150 ^e	60	40	150	66	165
150 ^f	70	40	150	77	165
200	95	80	200	105	220

^aSee 5.2.11

^bPower-frequency dew withstand test voltages on the insulators that meet these values is satisfactory in lieu of this test, provided the design of the complete device does not decrease the power-frequency withstand test voltages of the insulators.

^cWhen fuse enclosure packages use a liquid or a gas other than air for its dielectric medium, the dew test is not required.

^dWhen fuse enclosure packages use air for the dielectric medium, multipole devices require dew tests pole-to-pole only when there is a solid type insulation between the poles.

^eThese test voltages apply for fuses rated 23.0 kV to 27 kV.

^fThese test voltages apply for fuses rated 38 kV.

Line-type capacitor fuses, used outdoors or when used in containers or enclosures shall be capable of withstanding the test voltages of the appropriate outdoor or indoor Class A or B fuse device, as specified in Table 10, Table 11, Table 12, and Table 13 and when tested as specified in Clause 8.

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

8.1.2 Measurement of test voltages

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

8.1.3 Electrical connections

Electrical connections shall be made by means of bare conductors connected to each terminal. These conductors shall project from the terminals of the fuse in a straight line substantially parallel to the fuse unit or fuseholder for an unsupported distance of at least the break distance {isolating distance} of the fuse.

In the case of a fuse cutout 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 support 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.

8.1.4 Test arrangement

8.1.4.1 Terminal-to-ground tests

The fuse unit or fuseholder, 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 base or mounting bracket shall be grounded.

8.1.4.2 Terminal-to-terminal tests

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

- a) For fuse disconnecting switches, the fuse unit or fuseholder in the fully open position
- c) For dropout fuses, with the fuseholder or fuse unit in the dropout position
- d) For non-dropout fuses, with the fuseholder 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 or mounting bracket shall not be grounded. The tests shall be repeated with the high-voltage and ground leads reversed.

A Class B {power class} fuse or fuse disconnecting switch shall be mounted with its base insulated from a grounded metal structure by means of suitable insulator units to prevent flashover to ground.

8.2 Power-frequency dry-withstand voltage tests

8.2.1 Application of test voltage

The test voltage specified, with appropriate atmospheric corrections, shall be applied to the device for 60 s, per IEEE Std 4. Seventy-five percent (75%) of the rated dry-withstand test voltage may be applied in one step and then gradually raised at a rate of about 2% of the test voltage per second.