



IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV)

STANDARDS

IEEE Power and Energy Society

Developed by the
Surge Protective Devices Committee

IEEE Std C62.11™-2020
(Revision of IEEE Std C62.11-2012)



IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV)

Developed by the

Surge Protective Devices Committee
of the
IEEE Power and Energy Society

Approved 6 May 2020

IEEE SA Standards Board

Abstract: Metal-oxide surge arresters (MOSAs) designed to repeatedly limit the voltage surges on 48 Hz to 62 Hz power circuits (>1000 V) by passing surge discharge current and automatically limiting the flow of system power current are addressed in this standard. This standard applies to devices for separate mounting and to devices supplied integrally with other equipment. The tests demonstrate that an arrester is able to survive the rigors of reasonable environmental conditions and system phenomena while protecting equipment and/or the system from damaging overvoltages caused by lightning, switching, and other undesirable surges.

Keywords: charge transfer, discharge current, discharge voltage, IEEE C62.11™, lightning protection, maximum continuous operating voltage, MCOV, metal-oxide disk, metal-oxide surge arrester, MOSA, single-impulse charge transfer rating, surge arrester, thermal charge transfer rating, thermal energy withstand rating, TOV

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Introduction

This introduction is not part of IEEE Std C62.11-2020, IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV).

Metal-oxide surge arresters (MOSAs) described in this standard represent the predominant surge arrester technology applied on ac power systems above 1 kV. This standard presents minimum criteria for the testing of such surge arresters. Matters of application of this type of surge arrester are covered in IEEE Std C62.22™.¹ For testing and application of surge protective devices for use in low-voltage circuits (1 kV and below), other standards in the IEEE C62 series are available.

This edition contains the following significant changes from IEEE Std C62.11™-2012:

Clause 2	Added Reference to CIGRE TB 696
Clause 2	Added Reference to IEC 60071-2
Clause 3 Duty-cycle Voltage	Modified definition to indicate it is an obsolete term.
Clause 3 Single Impulse Charge transfer rating	Modified the definition of single impulse withstand rating to reflect charge transfer withstand and term Q_{rs}
Clause 3 Thermal Charge Transfer Rating	Added thermal charge transfer rating definition Q_{th}
Clause 3 Thermal Energy Withstand Rating	Added thermal energy withstand rating definition and term W_{th}
4.1.2 c)	Change usual service conditions to 1000 m (3281 ft) from 1800 m.
4.2.1 c)	Changed unusual service conditions to altitude exceeding 1000 m (3281 ft). Removed any specific ranges above 1000 m.
Clause 5	Modified Table 1 to reflect the trend toward elimination of duty-cycle voltage rating that is being replaced with MCOV as the relevant voltage rating of an arrester.
Clause 6 Table 2	Agreed to leave as is until all changes are made in the standard and then make the table right.
Clause 6 Table 3, Table 4, Table 5	Created Arrester Classification Table 3, Table 4, and Table 5 that replaces Table 6, Table 7, Table 12, and Table 13 of the 2012 edition. Also removed reference to system voltage and converted to MCOV levels instead.
7.2.2.3.3	Modified the type of voltage that can be used to heat the metal-oxide disks from only ac to include ac and dc.
8.1.2.1 a)1), a)2)	Modified test parameters for distribution arresters to align with IEC 60099-4. Added option to waive test with sufficient strike distance.
8.1.2.1 b)	Modified test parameters for distribution arresters to align with IEC 60099-4 and add option to waive test.
8.1.2.3	Modified Deadfront arrester test level table. Eliminated dc test and brought it in line with IEEE Std 386™.

¹Information on references can be found in Clause 2.

8.1.2.4	Modified test parameters and test methods for insulation withstand voltages for arrester housings. Changed parameters for arresters with MCOV < 140 kV Changed test method to switching impulse from power frequency tests for arrester with MCOV $\geq$ 140 kV and < 460 kV. For arresters applied to systems above 800 kV the test voltage will be negotiated between supplier and customer. Made provision for no test if the strike distance of the arrester is above a specific level. (Adopted a less conservative level than IEC in anticipation of the future change to the IEEE formula.) Added reference to IEEE Std 4™ and requirement for 15 impulses.
8.2.2.1	Deleted old Table 6 and rolled it into Summary Table 4.
8.2.2.2	Deleted old Table 7 and rolled it into Summary Table 4.
8.4.2.1.1	Modified Table 8 to reflect MCOV instead of rated voltage, and deleted less than 3 kV row since there are no ratings below that.
8.8.2.3	Replaced new paragraph e) that was dropped by mistake and added clearer test sequence. Also removed the requirement to inspect the internal components.
Previous Subclause 8.11	Eliminated Subclause 8.11 Partial Discharge Test as a design test since it is a routine test.
Previous Subclause 8.12	Eliminated the high-current short-duration test as a stand-alone test and folded it into the new Operating Duty Test.
Previous Subclause 8.13	Eliminated the low-current long-duration test for distribution arresters since they are now included in the Q_{rs} test.
Previous Subclause 8.14, new Subclause 8.11	The switching impulse energy rating test was modified by eliminating the preconditioning surges at lower currents, since it has been demonstrated in technical studies that low current surges such as these do not age MOSA type arresters. A V_{rq} test is included at the start of the test to verify the MCOV rating of the sample. The 10 s TOV at the start of the thermal recovery portion of the test was modified to $1.25 \times \text{MCOV}$ to reflect the goal of eliminating duty cycle voltage as a test parameter in this standard. A graphic test procedure summary was added for clarity of the test procedure.
Previous Subclause 8.15, new Subclause 8.12	Adopted the term charge transfer rating Q_{rs} as the single-impulse withstand rating of arresters. Included distribution arresters in this test series. A test procedure graphic was added for clarity. Added distribution arresters to the tested classes to replace LCLD test. Both 8/20 and rectangular waveshapes allowed for distribution arresters.
Previous Subclause 8.16, new Subclause 8.13	The duty cycle test was revised as follows: Station and intermediate arresters exempt since this is a redundant test to switching impulse withstand test. Q_{th} parameter adopted as the charge transfer characteristic. Name changed to Operating Duty Test to distance this standard from the duty cycle rating parameter. Removed 20 impulse preconditioning test for non-gapped MOV, since studies have shown that low current impulses < 20 kA do not age MOSA arresters. Added high current impulse to preconditioning test to replace 20 lower current impulses. Changed thermal recovery voltage to MCOV or higher for all distribution arresters instead of just HD. (Text of draft accepted in March meeting.) Revised non-gapped graphic of test timeline and correlated to verbiage with labels (Draft 9). Added separate graphic of timeline and verbiage for gapped arresters. Added new subclause for gapped MOV arresters that combines some parts of IEC 60099-6 and IEEE Std C62.11-2012.

Previous 8.17, new Subclause 8.14	The TOV test was modified as follows: Eliminated the 0.01s TOV, since it is not likely to happen in the real world and tests laboratories cannot actually test this short time. Added V_{ref} test as an initial test to verify specimen MCOV. Reduced the longest required time down to 3600 s and required it instead of 10000 s. This better represents the real world based on input from utilities. Adopted the prior duty energy to be W_{th}. Modified wording to require a start temp of 60 °C not allowing for a 10 min delay between removing from oven and starting the test. Added procedure graphic for clarification of test. Changed pass criteria of discharge voltage to $\pm 5\%$ from 10% to make consistent with other design tests.
Previous Subclause 8.21, new Subclause 8.18	Eliminated ODC, HCSD, and LCLD withstand tests and added single impulse charge transfer tests in their place and operating duty tests.
Previous Subclause 9.5	Eliminated subclause because there is no need to specify both creep distance and withstand voltage of a sample. Withstand voltage requirement remains.
Clause 11	Eliminated the clause based on lack of use and no rationale to keep.
Table C.1	Split table into Table C.1 and Table C.2, added new Q_{rs} and W_{th} values, and removed reference to rated voltage.
D.8.1	Modified rationale for most of the insulation withstand tests.
D.8.9	Updated historical note with more information.
Rationale removed	Low-current long-duration test, partial discharge test, high-current short-duration.
D.8.11	Updated to new procedure.
D.8.12	Updated to new procedure.
D.8.13	Updated to new procedure.
D.8.14	Updated to modified procedure.

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1. Overview

1.1 Scope

This standard applies to metal-oxide surge arresters (MOSAs) designed to repeatedly limit the voltage surges on 48 Hz to 62 Hz power circuits (>1000 V) by passing surge discharge current and automatically limiting the flow of system power current. This standard applies to devices for separate mounting and to devices supplied integrally with other equipment.

1.2 Purpose

To define tests that demonstrate that an arrester can survive the rigors of reasonable environmental conditions and system phenomena while protecting equipment and/or the system from damaging over voltages caused by lightning, switching, and other system disturbances.

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.

ASTM A153/153M, Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.^{2†}

ASTM D750, Standard Test Method for Rubber Deterioration in Carbon-Arc Weathering Apparatus.

ASTM D1499, Standard Practice for Operating Light And Water Exposure Apparatus (Carbon-Arc Type) for Exposure Of Plastics.

ASTM D2565, Standard practice for xenon arc exposure of plastics intended for outdoor applications.

ASTM G153, Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials.

ASTM G154, Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.

ASTM G155, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials.

[CIGRE TB 696-2017, MO Arresters for Emerging Systems.](#)³

^{2†} ASTM publications are available from the American Society for Testing and Materials (<http://www.astm.org/>).

³ CIGRE publications are available from the Council on Large Electric Systems (<http://www.e-cigre.org/>).

[IEC 60071-2, Insulation Coordination—Part 2: Application Guide.](#)⁴

[IEC 60099-4, Surge Arresters—Part 4: Metal-oxide surge arresters without gaps for a.c. systems.](#)

IEEE Std 4TM, IEEE Standard Techniques for High-Voltage Testing.^{5, 6}

IEEE Std 386TM, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.

IEEE Std 693TM, IEEE Recommended Practice for Seismic Design of Substations.

IEEE Std 1313.2TM-1999, IEEE Guide for the Application of Insulation Coordination.

IEEE Std C37.42TM, IEEE Standard Specifications for High-Voltage (> 1000 V) Expulsion-Type Distribution-Class Fuses, Fuse and Disconnecting Cutouts, Fuse and Disconnecting Switches, and Fuse Links, and Accessories Used with These Devices.^{2, 3}

IEEE Std C37.301TM, IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques—Partial Discharge Measurements.

IEEE Std C62.22TM, IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating Current Systems.

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[NEMA 107, Methods of Measurement of Radio Influence Voltage \(RIV\) of High Voltage Apparatus.](#)⁷

~~NEMA-CC-1, Electric Power Connection for Substations.~~⁴

3. Definitions, acronyms, and abbreviations

3.1 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.^{8 5}

arrester: *See:* **surge arrester.**

arrester, deadfront type: An arrester assembled in a shielded housing providing system insulation and conductive ground shield, intended to be installed in an enclosure for the protection of underground and pad-mounted distribution equipment and circuits.

arrester disconnect: A means for disconnecting an arrester in anticipation of, or after, a failure in order to prevent a permanent fault on the circuit and to give indication of a failed arrester.

NOTE—Clearing of the fault current through the arrester during disconnection is generally done by the nearest source side overcurrent-protective device.^{9 6}

arrester, distribution, heavy duty class: An arrester normally used to protect overhead distribution systems exposed to severe lightning currents.

⁴~~NEMA publications are available from Global Engineering Documents (<http://global.ihs.com/>).~~

⁷[NEMA publications are available from the National Electrical Manufacturers Association \(<http://www.nema.org/>\).](http://www.nema.org/)

^{8 5} *IEEE Standards Dictionary Online* ~~subscription~~ 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 http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

^{9 6} Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

arrester, distribution, light duty class: An arrester normally installed on and used to protect underground distribution systems where the major portion of the lightning stroke current is discharged by an arrester located at the overhead line/cable junction.

arrester, distribution, normal duty class: An arrester normally used to protect overhead distribution systems exposed to normal lightning currents.

arrester, liquid-immersed type: An arrester designed for use immersed in an insulating liquid.

arrester, riser pole type: An arrester for pole mounting normally used to protect underground distribution cable and equipment.

arrester unit: Any section of a multi-unit arrester.

basic lightning impulse insulation level (BIL): The electrical strength of insulation expressed in terms of the crest value of a standard lightning impulse. The basic lightning impulse insulation level (BIL) may be either a STATISTICAL BIL, or a CONVENTIONAL BIL. *See also:* **conventional basic lightning impulse insulation level (BIL); statistical basic lightning impulse insulation level (BIL).**

basic switching impulse insulation level (BSL): The electrical strength of insulation expressed in terms of the crest value of a standard switching impulse. The basic switching impulse insulation level (BSL) may be either a STATISTICAL BSL, or a CONVENTIONAL BSL. *See also:* **conventional basic switching impulse insulation level (BSL); statistical basic switching impulse insulation level (BSL).**

certification tests: Tests run on a regular, periodic basis to verify that selected, key performance characteristics of a product or representative samples thereof have remained within performance specifications.

classification of arresters: Arrester classification is determined by prescribed test requirements of this standard. These classifications are: station, intermediate, distribution heavy duty, distribution normal duty, [and](#) distribution light duty.

classifying current: The designated current used to perform the classification tests. [It is used in two forms: lightning impulse classifying current and switching impulse classifying current. Lightning impulse classifying current is also designated as \$I_{class}\$.](#)

conventional basic lightning impulse insulation level (BIL): Applicable specifically to non-self-restoring insulations. The crest value of a standard lightning impulse for which the insulation shall not exhibit disruptive discharge when subjected to a specific number of applications of this impulse under specified conditions. *See also:* **statistical basic lightning impulse insulation level (BIL).**

conventional basic switching impulse insulation level (BSL): Applicable specifically to non-self-restoring insulations. The crest value of a standard switching impulse for which the insulation does not exhibit disruptive discharge when subjected to a specific number of applications of this impulse under specified conditions. *See also:* **statistical basic switching impulse insulation level (BSL).**

corona ring: A metal part, usually circular or oval in shape, mounted to provide electrical shielding to terminals and other metal fitting to suppress the generation of corona on the terminals or fittings.

cracking: The rupture of the weathershed material to depths greater than 0.1 mm.

crest (peak) value (of a wave, surge, or impulse): The maximum value that a wave, surge, or impulse attains.

design tests: Tests made on each design to establish the performance characteristics and to demonstrate compliance with the appropriate standards of the industry. Once made, they need not be repeated unless the design is changed so as to modify performance.

discharge current: The surge current that flows through an arrester.

discharge voltage: The voltage that appears across the terminals of an arrester during passage of discharge current.

discharge voltage-current characteristic: The variation of the crest values of discharge voltage with respect to discharge current.

NOTE—This characteristic is normally shown as a graph based on three or more current-surge measurements of the same wave shape but of different crest values.

discharge withstand current: The specified magnitude and wave shape of a discharge current that can be applied to an arrester a specified number of times without causing damage to it.

disruptive discharge: The sudden and large increase in current through an insulating medium, due to the complete failure of the medium under the electrostatic stress.

duty-cycle voltage rating: [Historically](#) The designated maximum permissible voltage between its terminals at which an arrester is designed to perform its duty cycle. [The duty-cycle rating of arresters was more appropriate to the previous generation of arresters and is being phased out of this standard.](#)

electrical unit: Portion of an arrester in which each end of the unit is terminated with an electrode [that](#) ~~which~~ is exposed to the external environment.

fault current: The current from the connected power system that flows in a short circuit.

flashover: A disruptive discharge around or over the surface of a solid or liquid insulator.

front-of-wave (FOW) discharge voltage: [The crest discharge voltage resulting from a current wave at lightning impulse classifying current magnitude with a virtual front time of 1 \$\mu\$ s.](#)

front-of-wave impulse sparkover voltage: The impulse sparkover voltage with a wave front that rises at a uniform rate and causes sparkover on the wave front.

gapless: Not possessing gaps, series, or parallel as in *gapless arrester*.

grading or control ring: A metal part, usually circular or oval in shape, mounted to modify electrostatically the voltage gradient or distribution.

ground terminal: The conducting part provided for connecting the arrester to ground.

impulse: A surge of unidirectional polarity.

impulse protective level: For a defined wave shape, the higher of the maximum sparkover value or the corresponding discharge-voltage value.

impulse protective volt-time characteristic: The discharge-voltage time response of the device to impulses of a designated wave shape and polarity, but of varying magnitudes.

NOTE—For a gapless arrester, the impulse protective level is simply the corresponding discharge-voltage value.

impulse sparkover voltage: The highest value of voltage attained by an impulse of a designated wave shape and polarity applied across the terminals of an arrester that will cause gap sparkover prior to the flow of discharge current.

impulse sparkover volt-time characteristic: The gap sparkover response of the device to impulses of a designated wave shape and polarity, but of varying magnitudes.

NOTE—For an arrester, this characteristic is shown by a graph of crest voltage values plotted against time to sparkover.

indoor arrester: An arrester that, because of its construction, must be protected from the weather.

ionization current: The electric current resulting from the movement of electric charges in an ionized medium, under the influence of an applied electric field.

lightning: An electric discharge that occurs in the atmosphere between clouds or between clouds and ground.

lightning [impulse surge](#): A transient electric disturbance in an electric circuit caused by lightning.

line terminal: The conducting part of the arrester provided for connecting the arrester to the circuit conductor.

maximum continuous operating voltage (MCOV): The maximum designated root-mean-square (rms) value of power-frequency voltage that may be applied continuously between the terminals of the arrester.

maximum design cantilever load-static (MDCL-static): The maximum cantilever load the surge arrester is designed to continuously carry.

maximum system voltage: The highest voltage at which a system is operated.

NOTE—This is generally considered to be the maximum system voltage as prescribed in ANSI Std C84.1 [B1 B3].^{10 7}

mechanical unit: Portion of an arrester in which the metal-oxide disks ~~varistors~~ within the unit are mechanically restrained from moving in an axial direction.

metal-oxide disk ~~varistor~~: A two-terminal resistive element, composed of an electronic semiconductor and suitable contacts that has a markedly nonlinear volt-ampere characteristic.

metal-oxide surge arrester (MOSA): A surge arrester utilizing metal-oxide disks ~~varistors~~ fabricated from nonlinear resistance metal-oxide materials.

nominal rate of rise (of an impulse wave front): The slope of the line that determines the virtual zero. It is usually expressed in volts or amperes per microsecond.

nominal system voltage: A nominal value assigned to designate a system of a given voltage class.

NOTE—See ANSI Std-C84.1 [B1 B3].

normal lightning current: Lightning currents of 65 kA or less. *See also: severe lightning current.*

outdoor arrester: An arrester that is designed for outdoor use.

partial discharge (PD): A localized electric discharge resulting from ionization in an insulation system when the voltage stress exceeds the critical value. This discharge partially bridges the insulation between electrodes.

^{10 7}The numbers in brackets correspond to those of the bibliography in Annex E.

power-frequency sparkover voltage: The root-mean-square (rms) value of the lowest power-frequency sinusoidal voltage that will cause sparkover when applied across the terminals of an arrester.

power-frequency withstand voltage: A specified root-mean-square (rms) test voltage at a power frequency that will not cause a disruptive discharge.

production tests: *See: routine tests.*

prorated section: A complete, suitably housed part of an arrester, comprising all necessary components, including gaseous medium, in such a proportion as to accurately represent, for a particular test, the characteristics of a complete arrester.

prospective current (surge arresters) (available current): The ~~rms symmetrical~~ steady state current that would flow at a given point in a circuit if the arrester(s) at that point were replaced by links of zero impedance.

NOTE 1—This value can be in terms of either symmetrical or asymmetrical, peak or root-mean-square (rms) current, as specified.

NOTE 2—In some resonant circuits, the maximum available short-circuit current may occur when the short circuit is placed at some other point than the given one where the available current is measured.

puncture: Term used to denote either (A) A disruptive discharge through a solid dielectric; (B) A disruptive discharge through solid insulation; or (C) ~~Term used to denote when~~ a disruptive discharge ~~occurs~~ through a solid dielectric that and produces permanent loss of dielectric strength (; in a liquid or gaseous dielectric, the loss may be only temporary).

radio-influence voltage (RIV): A high-frequency voltage, generated by all sources of ionization current that appears at the terminals of electric-power apparatus or on power circuits.

rated short-circuit current (I_s): Maximum claimed power frequency rms fault current that may flow through a failed arrester, as verified in the short circuit design test

rating: The designation of an operating limit for a device.

reference current (I_{ref}): The peak value of the resistive component of a power-frequency current high enough to make the effects of stray capacitance of the arrester negligible. ~~This current level shall be specified by the manufacturer.~~

NOTE— Depending on the arrester design, the reference current will typically be in the range of 0.05 mA to 1.0 mA per square centimeter of disk area.

reference voltage (V_{ref}): The lowest peak value independent of polarity of power-frequency voltage, divided by the square root of 2, required to produce a resistive component of current equal to the reference current of the arrester or arrester element. The reference voltage of a multi-unit arrester is the sum of the reference voltages of the series units. ~~The voltage level shall be specified by the manufacturer.~~

routine tests: Tests made by the manufacturer on every device or representative samples, or on parts or materials, as required, to verify that the product meets the design specifications.

series gap: Intentional gap(s) between spaced electrodes in series with the [metal-oxide disks](#) ~~varistors~~ across which all or part of the impressed arrester terminal voltage appears.

severe lightning current: Lightning currents greater than 65 kA, but not greater than 100 kA. *See also: normal lightning current.*

shunt gap: Intentional gap(s) between spaced electrodes that is electrically in parallel with one or more [metal-oxide disks](#) ~~varistors~~.

single impulse [charge transfer](#) with stand rating (Q_{rs} of an arrester): The maximum charge of a single current impulse that the arrester can withstand multiple times during its life without causing [unacceptable](#) physical or electrical damage to the [metal-oxide disks](#) ~~varistors~~ of the arrester.

sparkover: A disruptive discharge between electrodes of a measuring gap, voltage-control gap, ~~or~~ gap-type protective device.

statistical basic lightning impulse insulation level (BIL): Applicable specifically to self-restoring insulations. The crest value of a standard lightning impulse for which the insulation exhibits a 90% probability of withstand (or a 10% probability of failure) under specified conditions. *See also:* **conventional basic lightning impulse insulation level (BIL).**

statistical basic switching impulse insulation level (BSL): Applicable specifically to self-restoring insulations. The crest value of a standard switching impulse for which the insulation exhibits a 90% probability of withstand (or a 10% probability of failure) under specified conditions. *See also:* **conventional basic switching impulse insulation level (BSL).**

surge arrester: A protective device for limiting surge voltages on equipment by diverting surge current and returning the device to its original status. It is capable of repeating these functions as specified.

NOTE—Hereafter, the term *arrester* as used in this should be understood to mean *surge arrester*.

~~**switching surge energy rating (of an arrester):** The maximum energy that an arrester can absorb and remain stable at normal operating voltage.~~

system voltage: The root-mean-square (rms) power-frequency voltage from line to line as distinguished from the voltage from line to neutral.

terminals: The conducting parts provided for connecting the arrester across the insulation to be protected.

time-to-impulse sparkover: The time between virtual zero of the voltage ~~impulses~~ ~~impulse~~ causing sparkover and the point on the voltage wave at which sparkover occurs.

thermal charge transfer rating (Q_{th}): The maximum charge transfer capability with thermal recovery of an arrester as demonstrated in the operating duty test.

thermal energy withstand rating (W_{th}): The maximum energy injection capability with thermal recovery of an arrester as demonstrated in the switching impulse energy rating test.

tracking: Irreversible degradation of [the surface of insulating](#) material from the formation of conductive carbonized paths.

ultimate mechanical strength-static (UMS-static): The load at which any part of the surge arrester fails to perform its mechanical function.

unit operation: A discharge of a surge through an arrester while the arrester is energized.

vent: An intentional opening for the escape of gases to the outside.

virtual duration of wave front (of an impulse): (A) For voltage waves with wave front duration less than 30 μs , either full or chopped on the front, crest, or tail, 1.67 times the time for the voltage to increase from 30% to 90% of its crest value. (B) For voltage waves with wave front duration of 30 μs or more, the time taken by the voltage to increase from actual zero to maximum crest value. (C) For current waves, 1.25 times the time for the current to increase from 10% to 90% of crest value.

virtual zero point (of an impulse): The intersection with the time axis of a straight line drawn through points on the front of the current wave at 10% and 90% crest value, or through points on the front of the voltage wave at 30% and 90% crest value.

wave: The variation with time of current, potential, or power at any point in an electric circuit.

wave front (of a surge or impulse): That part that occurs prior to the crest value.

wave shape (of an impulse test wave): The graph of the wave as a function of time.

wave shape designation (of an impulse): (A) The wave shape of an impulse (other than rectangular) of a current or voltage is designated by a combination of two numbers. The first, an index of the wave front, is the virtual duration of the wave front in microseconds. The second, an index of the wave tail, is the time in microseconds from virtual zero to the instant at which one-half of the crest value is reached on the wave tail. Examples are 1.2/50 and 8/20 waves. (B) The wave shape of a rectangular impulse of current or voltage is designated by two numbers. The first designates the minimum value of current or voltage that is sustained for the time in microseconds designated by the second number. An example is the 75 A 1000 μs wave.

wave tail (of an impulse): That part between the crest value and the end of the impulse.

withstand voltage: The voltage that electric equipment is capable of withstanding without failure or disruptive discharge when tested under specified conditions.

3.2 Acronyms and abbreviations

BIL basic lightning impulse insulation level

BSL basic switching impulse insulation level

CFO critical flashover voltage

CWW chopped wave withstand

DC direct current

FOW front of wave

HD heavy duty

I_{class} lightning impulse classifying current

I_{ref} reference current

I_s rated short-circuit current

LD light duty

MCOV maximum continuous operating voltage

MDCL maximum design cantilever load

MO metal-oxide

MOSA metal-oxide surge arrester

ND normal duty

PD partial discharge

Q_{rs} single impulse charge transfer rating

Q_{th} thermal charge transfer rating

RIV radio-influence voltage

TOV temporary overvoltage

UMS ultimate mechanical strength

V_C MCOV of prorated section

V_{REC} recovery voltage in thermal tests

V_{ref} reference voltage

W_{th} thermal energy withstand rating

4. Service conditions

4.1 Usual service conditions

4.1.1 General

An arrester conforming to this standard shall be capable of successful operation under the service conditions given in 4.1 ~~and 4.2~~.

4.1.2 Physical conditions

The following lists the acceptable physical conditions expected of an arrester:

- a) Ambient air temperature in the general vicinity of the arrester shall be between -40°C and $+40^{\circ}\text{C}$, ¹¹ ~~8~~ except in the following:
 - 1) Ambient air temperature in the general vicinity of deadfront arresters shall be between -40°C and $+65^{\circ}\text{C}$.
 - 2) Ambient liquid temperature in the general vicinity of liquid-immersed arresters shall be between -40°C and $+95^{\circ}\text{C}$.
- b) Maximum temperature of the arrester, due to external heat sources in the general vicinity of the arresters, shall not exceed 60°C , except in the following conditions:
 - 1) Maximum temperature of the deadfront arrester shall not exceed 85°C
 - 2) Maximum temperature of the liquid-immersed arresters shall not exceed 120°C
- c) Altitude shall not exceed 1000 ~~1800~~ m (3281 ~~6000~~ ft), except for liquid-immersed arresters

¹¹ ~~8~~ This operating temperature is suitable for arresters not mounted in proximity to external heat sources causing a continuous ambient temperature in the vicinity of the arrester in excess of 40°C .

4.1.3 System conditions

The following list is of acceptable system conditions for arrester covered in this standard:

- a) Nominal power system frequency of 48 Hz to 62 Hz
- b) System line-to-ground voltage within the voltage ratings of the arresters under all system operating conditions

4.2 Unusual service conditions

Exposure to any of the service conditions described in 4.2.1 and 4.2.2 may require special consideration in the design or application of arresters.

4.2.1 Physical conditions

The following list is of conditions outside the usual conditions expected of arresters in this standard:

- a) Ambient temperatures in the general vicinity of the arrester exceeding the values given in 4.1.2 ~~1~~
- b) Maximum arrester temperatures exceeding the values given in 4.1.2 ~~1~~
- c) Altitude exceeding 1000 ~~1800~~ m (3281 ~~6000~~ ft). ~~Arresters for service at higher altitudes shall be suitable for operation at either of the following altitude ranges:~~
 - ~~1) 1801 m–3600 m (6001 ft–12000 ft)~~
 - ~~2) 3601 m–5400 m (12001 ft–18000 ft)~~
- d) Exposure to any of the following:
 - 1) Damaging fumes or vapors
 - 2) Excessive dirt, salt spray, or other current-conducting deposits

- 3) Steam
- 4) Explosive atmospheres, abnormal vibrations, or shocks
- e) Unusual transportation or storage
- f) Earthquakes

4.2.2 System conditions

The following is a list of unusual system conditions for arresters covered in this standard:

- a) Nominal power frequency outside the range of ~~other than~~ 48 Hz to 62 Hz
- b) System operating conditions whereby the rating of the arrester may be temporarily exceeded. Some examples are as follows:
 - 1) Loss of neutral ground on normally grounded circuit
 - 2) Generator overspeed
 - 3) Resonance during fault upon loss of major generation
 - 4) System instability
 - 5) Single line-to-ground fault with delayed (abnormal) fault clearing
 - 6) Load rejection
 - 7) Ferroresonance
- c) Any other unusual conditions known to the user

5. Standard MCOV rating of an arrester and previously used duty-cycle rating

The relevant arrester voltage rating for MOSA type arresters is MCOV. The duty-cycle rating of arresters was more appropriate to the previous generation of arresters and is being phased out of this and future editions of this standard. Table 1 is a cross reference for common MCOV ratings of MOSA type arresters as well as the previously used duty-cycle rating associated with that specific MCOV rating.

NOTE—The duty-cycle rating is an obsolete term that is used here for historical reference only.

~~5. Standard voltage ratings: duty-cycle voltage and maximum continuous operating voltage (MCOV)~~

~~The standard root-mean-square (rms) duty-cycle voltage ratings and the corresponding rms MCOV rating are identified in Table 1.~~

Table 1 – Arrester ratings^a

MCOV (kV rms)	Duty-cycle voltage (kV rms)		MCOV (kV rms)	Duty-cycle voltage (kV rms)
2.55	3		115	144
5.1	6		131	168
7.65	9		140	172
8.4	10		144	180
10.2	12		152	192
12.7	15		180	228
15.3	18		190	240
17	21		209	258
19.5	24		212	264
22	27		220	276
24.4	30		230	288
29	36		235	294
31.5	39		245	312
36.5	45		318	396
39	48		335	420
42	54		353	444
48	60		372	468
57	72		392	492
70	90		428	540
76	96		448	564
84	108		462	576
98	120		470	588
106	132		485	612

[\(New\)](#)

Duty-cycle voltage (kV rms)	MCOV (kV rms)	Duty-cycle voltage (kV rms)	MCOV (kV rms)
3	2.55	144	115
6	5.1	168	131
9	7.65	172	140
10	8.4	180	144
12	10.2	192	152
15	12.7	228	180
18	15.3	240	190
21	17	258	209
24	19.5	264	212
27	22	276	220
30	24.4	288	230
36	29	294	235
39	31.5	312	245
45	36.5	396	318
48	39	420	335
54	42	444	353
60	48	468	372
72	57	492	392
90	70	540	428
96	76	564	448
108	84	576	462
120	98	588	470
132	106	612	485

(Deleted)

^aFor ratings not shown, consult with manufacturer.

6. Performance characteristics and tests

Each class and type of arrester shall be subjected to a series of design tests as listed in Table 2. For tests on liquid-immersed arresters that require immersion of the arrester in insulating liquid, the tests shall be performed for all types of insulating liquid in which the arrester is being qualified for use.

NOTE—A blank cell in Table 2 indicates that testing is not required.

Clause 7 contains general requirements for selection of test samples and for measurement practices. Clause 8 contains the specific requirements for each design test. Design test parameters are summarized for convenient reference in Table C.1 [and Table C.2](#).

Requirements for ~~certification tests and~~ routine tests are contained in Clause 11, ~~and Clause 12,~~ ~~respectively~~.

Table 2—Arrester design ~~tests~~ test

Design test	Station and intermediate class		Distribution class			
	Porcelain	Polymer	Porcelain	Polymer	Liquid-immersed	Deadfront
Arrester insulation withstand test	8.1.2.4	8.1.2.4	8.1.2.1	8.1.2.1	8.1.2.2	8.1.2.3
Discharge-voltage characteristics test	8.2	8.2	8.2	8.2	8.2	8.2
Power-frequency sparkover test	8.3	8.3	8.3	8.3	8.3	8.3
Impulse protective level voltage-time characteristic test	8.4	8.4	8.4	8.4	8.4	8.4
Accelerated aging test of metal-oxide disks	8.5	8.5	8.5	8.5	8.5	8.5
Accelerated aging test of polymer-housed distribution arresters with exposure to light and electrical stress	—	—	—	8.6	—	—
Accelerated aging test of polymer-housed arresters with exposure to salt fog	—	8.7	—	8.7	—	—
Contamination test	8.8	8.8	—	—	—	—
Distribution arrester seal integrity design test	—	—	8.9	8.9	—	—
Radio-influence voltage (RIV) test	8.10	8.10	—	—	—	—
Switching impulse energy rating test (W_{sh})	8.11	8.11	—	—	—	—
Single-impulse charge transfer rating test (Q_{st})	8.12	8.12	8.12	8.12	8.12	8.12
Operating duty test for distribution arresters (Q_{sh})	—	—	8.13	8.13	8.13	8.13
Temporary overvoltage (TOV) test	8.14	8.14	8.14	8.14	8.14	8.14
Short-circuit test	8.15	8.15	8.15	8.15	—	—
Failure mode test for liquid-immersed arresters	—	—	—	—	8.16	—
Deadfront arrester failure mode test	—	—	—	—	—	8.17
Distribution arrester disconnecter test	—	—	8.18	8.18	—	—
Maximum design cantilever load (MDCL) and moisture ingress test for polymer-housed arresters	—	8.19	—	8.19	—	—
Ultimate mechanical strength-static (UMS-static) test for porcelain-housed arresters	8.20	—	8.20	—	—	—
Seismic capability verification	8.21	8.21	—	—	—	—

(New)

Table 3, Table 4, and Table 5 list performance characteristics of different classes of arresters that are verified by design tests identified in Table 2.

Design test	Station and intermediate class		Distribution class			
	Porcelain	Polymer	Porcelain	Polymer	Liquid-immersed	Deadfront
Arrester insulation withstand test	8.1.2.4	8.1.2.4	8.1.2.1	8.1.2.1	8.1.2.2	8.1.2.2
Discharge-voltage characteristics test	8.2	8.2	8.2	8.2	8.2	8.2
Power-frequency sparkover test	8.3	8.3	8.3	8.3	8.3	8.3
Impulse protective level voltage-time characteristic test	8.4	8.4	8.4	8.4	8.4	8.4
Accelerated aging test of varistors	8.5	8.5	8.5	8.5	8.5	8.5
Accelerated aging test of polymer-housed distribution arresters with exposure to light and electrical stress				8.6		
Accelerated aging test of polymer-housed arresters with exposure to salt fog		8.7		8.7		
Contamination test	8.8	8.8				
Distribution arrester seal integrity design test			8.9	8.9		
Radio-influence voltage (RIV) test	8.10	8.10				
Partial discharge (PD) test	8.11	8.11	8.11	8.11	8.11	8.11
High-current short-duration withstand test			8.12	8.12	8.12	8.12
Low-current long-duration withstand test			8.13	8.13	8.13	8.13
Switching surge energy rating test	8.14	8.14				
Single-impulse withstand rating test	8.15	8.15				
Duty-cycle test	8.16	8.16	8.16	8.16	8.16	8.16
Temporary overvoltage (TOV) test	8.17	8.17	8.17	8.17	8.17	8.17
Short-circuit test	8.18	8.18	8.18	8.18		
Failure mode test for liquid-immersed arresters					8.19	
Deadfront arrester failure mode test						8.20
Distribution arrester disconnecter test			8.21	8.21		
Maximum design cantilever load (MDCL) and moisture ingress test for polymer-housed arresters		8.22		8.22		
Ultimate mechanical strength-static (UMS-static) test for porcelain-housed arresters	8.23		8.23			
Seismic capability verification	8.24	8.24				

(Deleted)

Table 3—Distribution arrester classifications

Distribution class arrester	Lightning impulse classifying current I_{class} (kA)	High current impulse (kA)	Minimum single impulse charge transfer rating Q_n (C)	Minimum thermal energy withstand rating Q_{th} (C)
Heavy Duty (HD)	10	100	0.4	1.1
Normal Duty (ND)	5	65	0.2	0.7
Light Duty (LD)	5	40	0.1	0.45

[\(New\)](#)

Table 4—Station and intermediate arrester impulse classifying currents

Arrester class	MCOV range (kV rms)	Lightning impulse classifying current I_{class} (kA)	Switching impulse classifying current (A)
Station	> 448	20	2000
Station	246–448	15	2000
Station	116–245	10	1000
Station	2.55–115	10	500
Intermediate	2.55–115	5	500

[\(New\)](#)

Table 5—Station and intermediate arrester thermal energy ratings

(W_{th})

Energy class	Minimum thermal energy withstand rating (W_{th}) kJ/kV-MCOV
A	3
B	4.5
C	6
D	7.5
E	9
F	11
G	13
H	15
J	18
K	21
L	24
M	27
N	30

(New)

7. Test requirements

7.1 Complete arrester test samples

The following list outlines the requirements of new test samples used in this standard:

- New and clean arresters shall be used for each test unless otherwise specified.
- All test samples for arrester designs incorporating a disconnecter, either as an integral part or an accessory, shall include the disconnecter.
- The arrester shall be mounted in the position(s) in which it is designed to be used.
- The arrester-mounting bracket, if used, shall be connected to the ground terminal.

- e) The grading/control ring and/or corona ring if used, shall be included in design tests influenced by stray capacitance effects.
- f) Deadfront arresters shall be properly assembled with actual or simulated components. All parts that are normally grounded shall be connected to the ground of the test circuit.

7.2 Prorated section

Several design tests permit the use of scaled representations of a complete arrester. These prorated sections shall be constructed so that they accurately represent the electrical and thermal characteristics of the represented arrester for the test being performed. The parameters of the prorated section depend on the particular design test being performed.

7.2.1 Prorating for discharge voltage tests

Tests may be made on open-air samples consisting of [metal-oxide disks](#) ~~varistors~~ only. The diameter of [metal-oxide disks](#) ~~varistors~~ used in the prorated section shall be the same as the diameter of the [metal-oxide disks](#) ~~varistors~~ used in the arrester being modeled. The maximum discharge voltage of the complete arrester for a given discharge current is given by Equation (1).

$$V_{d \max} = \text{discharge voltage measured on the prorated section at the given current} \times K_s \quad (1)$$

where

K_s is the prorated section scale factor, given by Equation (2)

$$K_s = V_{DA} / V_{DS} \quad (2)$$

where

V_{DA} is the maximum discharge voltage of the arrester at [lightning impulse](#) classifying current

V_{DS} is the discharge voltage measured on the prorated section at [lightning impulse](#) classifying current

7.2.2 Prorating for design test involving demonstration of thermal recovery

Design tests that involve application of power-frequency voltage and demonstration of thermal recovery (namely, TOV, [operating](#) ~~discharge current withstand~~, duty ~~cycle~~ and switching [impulse surge](#) energy rating tests) shall be performed on a model that properly represents the thermal characteristics of the complete arrester and its environment. The diameter of [metal-oxide disks](#) ~~varistors~~ used in the prorated section shall be the same as the diameter of the [metal-oxide disks](#) ~~varistors~~ used in the arrester being modeled.

The prorated section shall contain all organic components that are contained in the complete arrester, and they shall be in the same nominal quantity per unit length. The prorated section does not have to be a slice out of the complete arrester, and it does not have to contain the inorganic components (e.g., porcelain) used in the arrester.

The specific construction of the housed model depends on the arrester type (see 7.2.2.1 and 7.2.2.2).

The ~~duty cycle voltage rating (V_R) and~~ MCOV (V_C) of the prorated section ~~is~~ [are](#) given by Equation (3) ~~and Equation (4)~~.

$$\del{V_R = \text{arrester duty cycle voltage rating} / K_p} \quad (3)$$

$$V_C = \text{Arrester MCOV} / K_p \quad (3)$$

where

[V_C](#) is the MCOV of the prorated section

K_p is the prorated section scale factor

The prorated section scale factor shall be determined on the basis of reference voltage scaling or metal-oxide volume scaling, whichever results in the most conservative modeling. In other words, K_p shall be the lower of K_V or K_M where Equation (4) and Equation (5) apply.

$$K_V = V_{RA}/V_{RS} \text{ (reference voltage scaling factor)} \quad (4)$$

$$K_M = M_A/M_S \text{ (metal-oxide volume scaling factor)} \quad (5)$$

where

V_{RA} is the minimum reference voltage of arrester (specified by the manufacturer)

V_{RS} is the voltage measured on prorated section at [the manufacturer's specified](#) reference current

M_A is the minimum metal-oxide volume in the complete arrester (specified by the manufacturer)

M_S is the metal-oxide volume in the prorated section

In addition, the [metal-oxide disks](#) ~~varistors~~ used for the prorated section shall have a power-frequency power loss equal to the maximum allowed by the manufacturer in the arrester being modeled. In the event that maximum power loss [metal-oxide disks](#) ~~varistors~~ are not available, prorated sections may be constructed with lower power-loss [metal-oxide disks](#) ~~varistors~~ provided that the voltage applied during the thermal recovery portion of the test is adjusted as shown in Equation (6).

$V_{REC} = V_C \times K_W$
(6)

[\(New\)](#)

[where](#)

[V_{REC} is the Recovery voltage in tests where thermal recovery is required](#)

K_W is the power loss scale factor as defined in Equation (7)

$$\text{Recovery voltage} = V_C \times K_W \quad (7)$$

where Equation (8) applies:

$$K_W = V_{WT} / V_{WN} \quad (7)$$

(New)

$$K_W = V_{WT} / V_{WN} \quad (8)$$

(Deleted)

where

V_{WT} is the voltage required to increase power loss to maximum allowed level,
at the temperature at which power loss is normally measured

V_{WN} is the voltage at which power loss is normally measured

7.2.2.1 Outdoor arresters

Test models shall be constructed as follows:

- a) Housing length shall be great enough to enclose the prorated internal element(s), but shall not be more than 50% longer than the internal element(s). Housing length in excess of 10% longer than the internal element(s) shall be insulated both internally and externally with at least 5 cm thickness of uncompressed glass wool insulation or equivalent. The total mass of the housing in the model shall not exceed 110% of the mass of the housing in the section of the arrester being modeled.
- b) Both ends of the housing shall be closed using at least 5 cm (2 in) thickness of uncompressed glass wool insulation or equivalent, and the insulation shall be arranged to cover the ends of the housing. The thermal resistivity constant (R-value) of the insulation shall be five or greater.

- c) Maximum conductor size for electrical connections within the sample shall be 3 mm² (AWG # 12).

7.2.2.2 Liquid-immersed arresters

A requirement for liquid-immersed arresters has not yet been established. The manufacturer shall describe the thermal prorating procedure used. The thermal model shall take into account the thermal effects of the liquid and other major components that may be contained in the tank or vessel in which the arrester will be installed in the field.

7.2.2.3 Test to verify thermal equivalency between complete arrester and thermally prorated arrester section

If, for any test requiring demonstration of thermal recovery, a complete arrester cannot be tested, then a thermally prorated section shall be verified according to the procedure in this subclause. Once the prorated section has been verified for a given arrester type and design, the verification need not be repeated for future use of prorated sections of identical construction.

This procedure evaluates the validity of a thermally prorated section by heating it and a complete arrester to the same temperature, via internal power loss, and then by monitoring and comparing the cooling rates of the two devices with voltage switched off.

7.2.2.3.1 Ambient conditions

The complete arrester of the unit containing the most [metal-oxide disks](#) ~~varistors~~ per unit length of a multi-unit arrester is placed, along with the prorated section, in still air having an ambient temperature between 10 °C and 40 °C. The ambient temperature shall be the same ± 3 °C for the duration of each test.

NOTE—The broad temperature range is to accommodate laboratories where testing of complete arresters may have to be performed outside or in large chambers without temperature control.

7.2.2.3.2 Cooling rate monitoring methods

To determine the cooling rates of the arrester and of the prorated section, thermocouples, fiberoptic temperature sensing probes, or other types of sensors may be attached to the [metal-oxide disks](#) ~~blocks~~, or power loss or resistive component of current may be monitored. If power loss or resistive component of current is used, the complete arrester and the prorated section shall be made using [metal-oxide disks](#) ~~varistors~~ from the same lot.

If temperature sensors are used, they may be placed at a number of points and an average temperature calculated, or the temperature at any point located 1/3 to 1/2 of the arrester length from the top may be used. (Using the single point 1/3 to 1/2 length from the top gives a conservative result.)

7.2.2.3.3 Heating the [metal-oxide disks](#) ~~varistors~~

[Metal-oxide disks](#) ~~Varistors~~ in the complete arrester and in the prorated section shall be heated to a temperature of $140^{\circ}\text{C} \pm 10^{\circ}\text{C}$, ~~between~~ [within](#) 1 min to 120 min, by application of power-frequency ~~or dc~~ voltage with an amplitude above reference voltage. The temperature attained by the [metal-oxide disks](#) ~~varistors~~ in the complete arrester and in the prorated section shall be equivalent within 3°C . When this temperature is reached, the voltage source shall be disconnected.

The heating time for the complete arrester and the prorated section shall be the same within $\pm 5\%$.

NOTE— ~~(A shorter heating time is more representative of most field circumstances, but a longer heating time is conservative.)~~

7.2.2.3.4 Determination of cooling rate curve

Within 1 min after disconnecting the heating (voltage) source, begin monitoring the cooling rate using any of the methods in 7.2.2.3.2 at intervals not exceeding 5 min. Continue monitoring for a period of not less than 2 h.

If power loss or resistive component of current is used, MCOV shall be applied in a periodic manner for a time not exceeding 30 s to determine the measured quantity. Voltage-on time shall be kept as short as possible to most closely duplicate the result that would be obtained with thermocouples. In order to give a conservative result, voltage-on time for the prorated section shall not exceed voltage-on time for the complete arrester.

Draw a smooth curve through the temperature, power loss, or resistive component of current versus time measured points.

7.2.2.3.5 Evaluation

After the complete arrester and the prorated section cooling rate curves have been determined, the two curves shall be compared.

Thermal equivalency of the prorated section is verified provided that, for all instants during the cooling period, the monitored quantity (e.g., temperature, power loss, or resistive component of current) for the prorated section is equal to or higher than for the complete arrester. If, at any instant, the measured cooling curve of the section falls below the measured cooling curve of the complete arrester, compensation may be made by adding a fixed temperature to every point on the cooling curve of the section such that the adjusted cooling curve of the section is at or above the measured cooling curve of the complete arrester over the entire cooling period. The amount of this temperature adjustment shall be added to the prorated section temperature prior to energy injection in all tests that involve demonstration of thermal recovery.

If power loss is used, time zero power shall be set equal to 1 per unit for the arrester and 1 per unit for the prorated section in order to superimpose the starting points of the two curves.

7.3 Test measurements

Measurement practices shall be in accordance with the following:

- a) The specifications for the individual tests, as given in this standard.

- b) The specifications for dielectric tests, as given in IEEE Std 4.12⁹

7.4 Impulse test-wave tolerances

For all test waves in these standards, specifications per Table 6³ shall apply unless otherwise specified.

¹²⁹ Information on references can be found in Clause 2.

Table 6—Impulse ~~Impulsive~~ wave shapes

Measured quantity	1.2/50 μ s waves	250/2500 μ s waves	All other exponential waves
Crest value	$\pm 3\%$	$\pm 3\%$	$\pm 10\%$
Front time	$\pm 30\%$	$\pm 20\%$	$\pm 10\%$
Time to half value	$\pm 20\%$	$\pm 60\%$	$\pm 10\%$
Nominal rate of rise of wave front	—	—	$\pm 10\%$

(New)

Measured quantity	1.2/50 waves	All other exponential waves
Crest value	$\pm 3\%$	$\pm 10\%$
Front time	$\pm 30\%$	$\pm 10\%$
Time to half value	$\pm 20\%$	$\pm 10\%$
Nominal rate of rise of wave front	—	$\pm 10\%$

(Deleted)

7.5 Power-frequency test voltages

The power-frequency test voltages shall have a crest value equal to $\sqrt{2}$ times the specified rms voltage and shall have a waveshape approximating a sinusoid with both half cycles closely alike ~~an approximately sinusoidal shape~~.

8. Design tests

8.1 Arrester insulation withstand test

The purpose of the arrester insulation withstand test is to verify that, under usual system conditions, arrester housings will not flash over under defined impulse, switching, and power-frequency conditions. [The external insulation of arresters shall be subjected to withstand tests as per the relevant test procedure given in IEEE Std 4.](#)

8.1.1 Samples

Test samples shall be the assembled insulating members of the arrester or of a single unit. The internal parts of the arrester or unit shall be removed or rendered inoperative to permit these tests.

Any external series-gap electrodes shall be removed where the gap shunts an insulating member.

8.1.2 Procedure

Test procedures shall comply with Clause 7. Test voltages as described in 8.1.2.1, 8.1.2.2, 8.1.2.3, or

8.1.2.4 (depending on the class and type of arrester being tested) shall be applied to the test samples. Unless otherwise specified, the test voltages shall be applied between the arrester line and ground terminals.

8.1.2.1 Distribution arresters used in open air

Insulation withstand test voltages for distribution arresters used in open air shall be in accordance with the following:

- a) For gapless arresters, the 1.2/50 impulse withstand test voltage of the arrester shall be ~~the 1.30 42~~ times the maximum discharge voltage [at the arrester's lightning impulse classifying for a 20 kA 8/20 discharge](#) current. [The test voltage shall be applied 15 times for each polarity without flashover.](#)