

IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits

Sponsor

**Surge-Protective Devices Committee
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Abstract: Metal-oxide surge arresters designed to repeatedly limit the voltage surges on 48 Hz to 62 Hz power circuits by passing surge discharge current and automatically limiting the flow of system power current are discussed. This standard applies to devices for separate mounting and to those supplied integrally with other equipment.

Keywords: arrester, conformance tests, deadfront arrester, design tests, duty-cycle voltage rating, liquid-immersed arrester, metal-oxide surge arrester

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Introduction

(This introduction is not a part of IEEE Std C62.11-1993, IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits.)

This standard presents minimum criteria for the testing of metal-oxide surge arresters that are applied to ac power systems.

Metal-oxide surge arresters described in this standard are typically applied to ac power systems in place of other valve type arresters covered in IEEE Std C62.1-1989.* For protection of low-voltage circuits including vulnerable or susceptible electronics, the latest standards published under the C62 series should be consulted.

This standard is written for metal-oxide surge arresters both with or without spark gaps.

The following additions in this revision include:

- a) Fault withstand tests for distribution arresters
- b) TOV procedures
- c) Classifications for distribution normal duty and distribution light duty
- d) Several new types of arresters including
 - 1) Deadfront arresters
 - 2) Liquid-immersed arresters
 - 3) Polymer-housed arresters
- e) Routine tests for use in production of the arresters

Material for this standard was developed by Working Groups 3.3.8, 3.3.10, and 3.3.11 of the Overvoltage Protective Devices (OPD) Subcommittee, Surge Protective Devices (SPD) Committee.

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*Information on references can be found in clause 2.

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1. Scope

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

2. References

This standard shall be used in conjunction with the following publications:

ANSI C37.42-1989, American National Standard for Switchgear—Distribution Cutouts and Fuse Links—Specifications.¹

ANSI C84.1-1989, American National Standard Voltage Ratings for Electric Power Systems and Equipment (60 Hz).

ANSI C92.1-1982, American National Standard for Insulation Coordination.

ASTM A 153-82 (1987), Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.²

ASTM D 3487-1988, Specification for Mineral Insulating Oil Used in Electrical Apparatus.

IEEE Std C37.09-1979 (Reaff 1988), IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.³

IEEE Std C62.1-1989, IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits (ANSI).

IEEE Std C62.2-1987, IEEE Guide for Application of Gapped Silicon-Carbide Surge Arresters for Alternating Current Systems (ANSI).

IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing (ANSI).

IEEE Std 386-1985 (Reaff 1991), IEEE Standard for Separable Insulated Connectors for Power Distribution Systems Above 600 V (ANSI).

NEMA LA 1-1986, Surge Arresters.⁴

NEMA 107-1987, Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA. This particular standard is also available in the Supplement to IEEE Standards Collection, Circuit Breakers, Switchgear, Substations, and Fuses (C37), 1993 Edition from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P. O. Box 1331, Piscataway, NJ 08855-1331.

²ASTM publications are available from the Sales Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037, USA.

3. Definitions

The following definitions apply to metal-oxide surge arresters. They do not necessarily cover other applications.

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

3.2 arrester disconnecter: 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.

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

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

3.5 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.

3.6 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.

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

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

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

3.10 basic impulse insulation level (BIL): A reference impulse insulation strength expressed in terms of the crest value of withstand voltage of a standard full impulse voltage wave.

NOTE—See ANSI C92.1-1982.⁵

3.11 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.

3.12 classification of arresters: Arrester classification is determined by prescribed test requirements. These classifications are: station, intermediate, distribution heavy duty, distribution normal duty, distribution light duty, secondary.

NOTE—See annex B for summary of test requirements by classification.

3.13 conformance tests: Tests made, when required, to demonstrate selected performance characteristics of a product or representative samples thereof.

3.14 classifying current: The designated current used to perform the classification tests.

NOTE—See tables 3 and 4 in clause 8.

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

⁵Information on references can be found in clause 2.

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

3.17 current, normal lightning: Lightning currents of 65 kA or less.

3.18 current, severe lightning: Lightning currents greater than 65 kA but not greater than 100 kA.

3.19 deflector: A means for directing the flow of the gas discharge from the vent of the arrester.

3.20 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.

3.21 discharge counter: A means for recording the number of arrester discharge operations.

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

3.23 discharge indicator: A means for indicating that the arrester has discharged.

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

3.25 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.

3.26 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.

3.27 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.

3.28 duty-cycle voltage rating: The designated maximum permissible voltage between its terminals at which an arrester is designed to perform its duty cycle.

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

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

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

3.32 gapless: Not possessing gaps, series, or parallel as in “gapless arrester.”

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

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

3.35 impulse: A surge of unidirectional polarity.

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

3.37 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.

3.38 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.

3.39 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.

3.40 impulse withstand voltage: The crest value of an impulse that, under specified conditions, can be applied without causing a disruptive discharge.

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

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

3.43 ionization voltage: A high-frequency voltage appearing at the terminals of an arrester, generated by all sources, but particularly by ionization current within the arrester, when a power-frequency voltage is applied across the terminals.

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

3.45 lightning surge: A transient electric disturbance in an electric circuit caused by lightning.

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

3.47 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.

3.48 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 C84.1-1989.

3.49 metal-oxide surge arrester (MOSA): A surge arrester utilizing valve elements fabricated from non-linear resistance metal-oxide materials.

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

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

NOTE—See ANSI C84.1-1989.

3.52 operating duty cycle: One or more unit operations, as specified.

3.53 oscillatory surge: A surge that includes both positive and negative polarity values.

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

3.55 power-frequency sparkover voltage: The rms value of the lowest power-frequency sinusoidal voltage that will cause sparkover when applied across the terminals of an arrester.

3.56 power-frequency withstand voltage: A specified rms test voltage at power frequency that will not cause a disruptive discharge.

3.57 production tests: *See:* **routine tests.**

3.58 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.

3.59 puncture: Term used when a disruptive discharge occurs through a solid dielectric. A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

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

3.61 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.

3.62 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 cm of disk area.

3.63 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.

3.64 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.

3.65 series gap: Intentional gap(s) between spaced electrodes in series with the valve elements across which all or part of the impressed arrester terminal voltage appears.

3.66 shunt gap: Intentional gap(s) between spaced electrodes that is electrically in parallel with one or more valve elements.

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

3.68 surge: A transient wave of current, potential, or power in an electric circuit.

3.69 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 standard shall be understood to mean **surge arrester**.

3.70 system voltage: The rms power-frequency voltage from line-to-line as distinguished from the voltage from line-to-neutral.

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

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

3.73 tracking: Irreversible degradation of surface material from the formation of conductive carbonized paths.

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

3.75 valve arrester: An arrester that includes one or more valve elements.

3.76 valve element: A resistor that because of its nonlinear current-voltage characteristic, limits the voltage across the arrester terminals during the flow of discharge current and contributes to the limitation of follow current at normal power-frequency voltage.

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

3.78 virtual duration of wavefront (of an impulse): The virtual value for the duration of the wavefront is as follows:

- a) For voltage waves with wavefront 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 wavefront 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

3.79 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.

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

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

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

3.83 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 wavefront, is the virtual duration of the wavefront 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.

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

4. Service conditions

4.1 Usual service conditions

4.1.1 Physical conditions

- a) Ambient air temperature in the general vicinity of the arrester shall be between -40°C and 40°C ,⁶ except that
 - 1) Ambient air temperature in the general vicinity of deadfront arresters shall be between -40°C and 65°C
 - 2) Ambient liquid temperature in the general vicinity of liquid-immersed arresters shall be between -40°C and 95°C
- b) Maximum temperature of the arrester, due to external heat sources in the general vicinity of the arrester, shall not exceed 60°C , except that
 - 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 not exceeding 1800 m (6000 ft), except for liquid-immersed arresters

4.1.2 System conditions

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

4.2 Unusual service conditions

Exposure to any of the following service conditions may require special consideration in the design or application of arresters.

4.2.1 Physical conditions

- a) Ambient temperatures in the general vicinity of the arrester exceeding the values given in 4.1.1
- b) Maximum arrester temperatures exceeding the values given in 4.1.1
- c) Altitude exceeding 1800 m (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–12 000 ft)
 - 2) 3601 m–5400 m (12 001 ft–18 000 ft)
- d) Exposure to:
 - 1) Damaging fumes or vapors
 - 2) Excessive dirt; salt spray or other current-conducting deposits; steam; or explosive atmospheres, abnormal vibrations, or shocks
- e) Limitation on clearances to nearby conducting objects, particularly at altitudes exceeding 1800 m (6000 ft)
- f) Unusual transportation or storage

⁶This 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 .

4.2.2 System conditions

- a) Nominal power frequency other than 48 Hz to 62 Hz
- b) System operating conditions whereby the ratings of the arrester may be temporarily exceeded. Some examples are:
 - 1) Loss of neutral ground on normally grounded circuit
 - 2) Generator overspeed
 - 3) Resonance during faults upon loss of major generation
 - 4) System instability
 - 5) Persistent single line-to-ground fault on ungrounded three-phase systems
- c) Any other unusual conditions known to the user

5. Standard voltage ratings: Duty-cycle voltage and MCOV

The standard rms duty-cycle voltage ratings in kilovolts and the corresponding rms maximum continuous operating voltage (MCOV) rating are identified in table 1.

Table 1—Arrester Ratings in (kV) rms

Duty-cycle voltage	MCOV	Duty-cycle voltage	MCOV
3	2.55	132	106
6	5.10	144	115
9	7.65	168	131
10	8.40	172	140
12	10.20	180	144
15	12.70	192	152
18	15.30	228	180
21	17.00	240	190
24	19.50	258	209
27	22.00	264	212
30	24.40	276	220
36	29.00	288	230
39	31.50	294	235
45	36.50	312	245
48	39.00	396	318
54	42.00	420	335
60	48.00	444	353
72	57.00	468	372
90	70.00	492	392
96	76.00	540	428
108	84.00	564	448
120	98.00	576	462
		588	470
		612	485

NOTE—For ratings not shown, consult with the manufacturer.

6. Performance characteristics and tests

The following tests were developed to evaluate the relative performance of metal-oxide surge arresters. Test requirements by classification are listed in annex B.

6.1 Insulation withstand tests

The voltage withstand tests of arrester insulation demonstrate that the insulation of the arrester is above the minimum specified level (see 8.1).

6.2 Power-frequency sparkover tests

This test applies only to gapped arrester designs that utilize grading currents of less than 1.0 A to cause power-frequency sparkover. It demonstrates that the power-frequency sparkover of the arrester is greater than the arrester MCOV rating by a specified margin (see 8.2).

6.3 Discharge-voltage tests

Discharge-voltage tests serve to establish the relation between the voltage across the arrester terminals and discharge current at several values of discharge current of specified wave shape. They also show the relation between discharge voltage and arrester rating so that the discharge-voltage characteristics of high-voltage arresters may be determined by extrapolation (see 8.3).

6.4 Impulse protective level tests

The impulse protective level test is applicable only to arrester designs that undergo a sparkover mode and serves to demonstrate whether the protective margin is defined by the arrester's sparkover voltage or its discharge voltage for a specified wave shape (see 8.4).

6.5 Discharge-current withstand tests

The discharge-current withstand tests, consisting of high-current, short-duration and low-current, long-duration tests, serve to demonstrate the adequacy of the electrical, mechanical, and thermal design of the arrester (see 8.6).

6.6 Duty-cycle test

The duty-cycle test serves to establish the ability of the arrester to discharge-impulse current while energized at duty-cycle voltage and thermally recover at MCOV (see 8.7).

6.7 Radio-influence voltage test

The radio-influence voltage test provides a measure of arrester-generated, high-frequency voltage that may cause objectionable communication interference (see 8.8).

6.8 Internal-ionization voltage test

The internal-ionization voltage test provides a measure of ionization current present within an arrester design. This may cause deterioration of internal arrester parts (see 8.8).

6.9 Pressure-relief/fault-current withstand tests

The pressure-relief/fault-current withstand tests serve to demonstrate that failed arresters will conduct fault current under specified conditions without violent disintegration (see 8.9 and 8.10).

6.10 Contamination tests

The contamination tests serve to demonstrate that the arrester will withstand a prescribed power-frequency voltage under prescribed surface contamination without flashover or thermal runaway (see 8.12).

6.11 Disconnecter tests

The disconnector tests serve to demonstrate that disconnectors can withstand, without operation, the arrester design tests and provide a current-time characteristic operating curve (see 8.11).

6.12 Accelerated aging procedure

The accelerated aging procedure provides a method to simulate the long-term effects of voltage and temperature on design parameters significant to the arrester performance (see 8.5 and 8.16).

6.13 Failure mode tests

The failure mode tests serve to demonstrate failure mode for liquid-immersed and deadfront arresters (see 8.13 and 8.14).

6.14 Temporary overvoltage tests

The purpose of these tests is to determine TOV capability of the arrester (see 8.15).

6.15 Seal integrity design test

This test is performed to assure seal integrity of the arrester design (see 8.17).