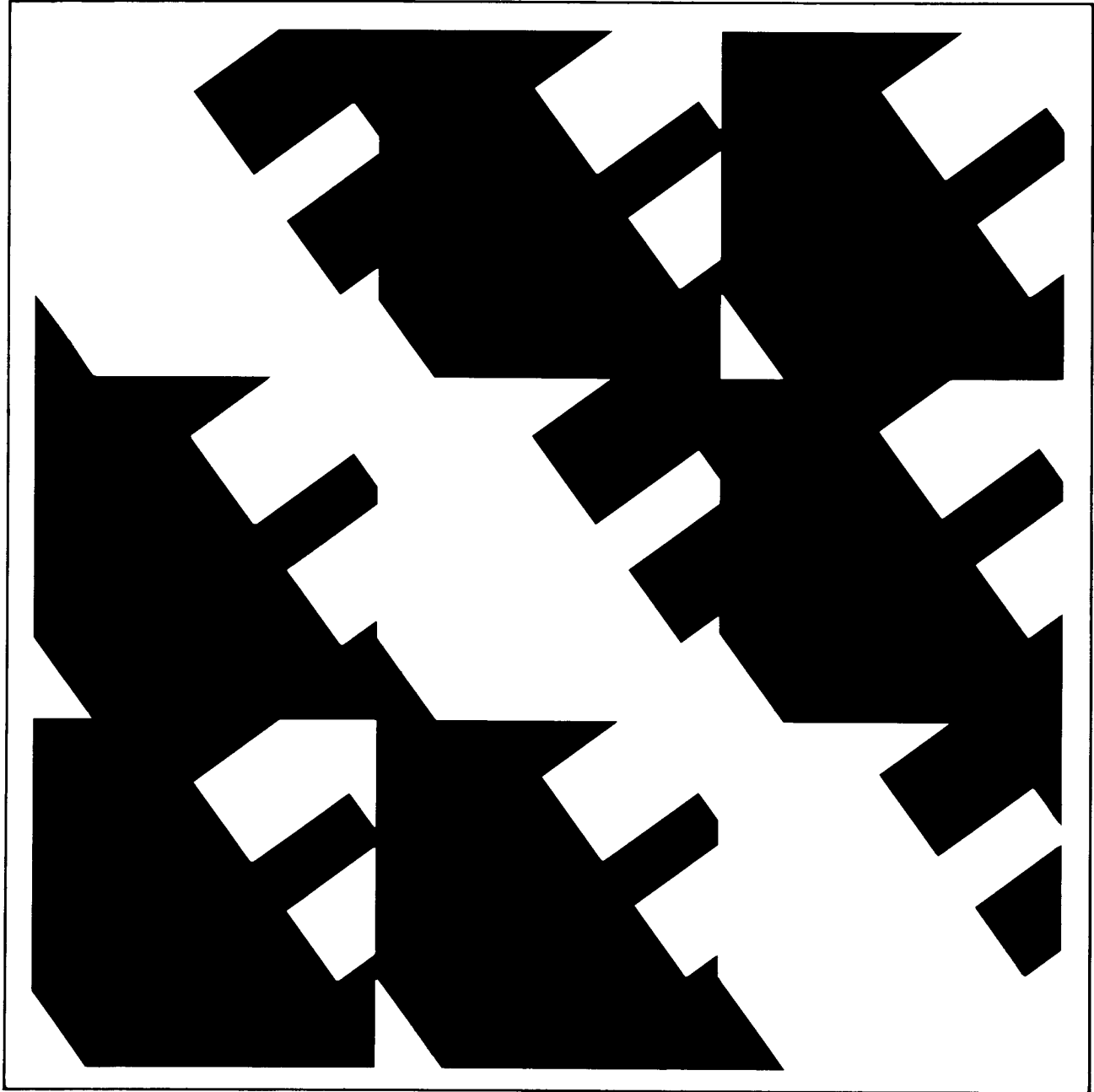


IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits

ANSI/IEEE C62.11-1987



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IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits

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. Definitions

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

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.

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 [4].¹

¹ The numbers in brackets correspond to those of the references listed in Section 3 of this standard.

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. These classifications are:

- (1) Station
- (2) Intermediate
- (3) Distribution
 - (a) Heavy duty
 - (b) Normal duty
- (4) Secondary

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

classification current. The designated current used to perform the classification tests.

NOTE: See Tables 3 and 4.

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

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

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

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

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

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

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 impulse sparkover voltage. The impulse sparkover voltage with a wavefront that rises at a uniform rate and causes sparkover on the wavefront.

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 waveshape, 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.

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 values of crest voltage plotted against time to sparkover.

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

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.

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.

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

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

line terminal. The conducting part 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 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 C84.1-1982 [3].

metal-oxide surge arrester (MOSA). A surge arrester utilizing valve elements 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 C84.1-1982 [3].

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

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

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

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.

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

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.

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

radio-influence voltage (RIV). A high-frequency voltage, generated by all sources of ion-

ization current, that appears at the terminals of electric-power apparatus or on power circuits.

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

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

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

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

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.

system voltage. The 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 impulse causing sparkover and the point on the voltage wave at which sparkover occurs.

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

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

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.

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

virtual duration of wave front (of an impulse). The virtual value for the duration of the wave front is as follows:

(1) For voltage waves with wave front duration less than 30 μ s, 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.

(2) For voltage waves with wave front duration of 30 μ s or more, the time taken by the voltage to increase from actual zero to maximum crest value.

(3) 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 which 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).

(1) 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.

(2) 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 μ s wave.

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

3. References

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

- [1] ANSI C37.42-1981, American National Standard Specifications for Distribution Cutouts and Fuse Links.²
- [2] ANSI C62.2-1981, American National Standard: Guide for Application of Valve Type Surge Arresters for Alternating-Current Systems.
- [3] ANSI C84.1-1982, American National Standard Voltage Ratings for Electric Power Systems and Equipment (60 Hz).
- [4] ANSI C92.1-1982, American National Standard for Insulation Coordination.
- [5] ANSI/IEEE C37.09-1979, IEEE Standard Test Procedure for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.³
- [6] ANSI/IEEE C62.1-1984, IEEE Standard for Surge Arresters for AC Power Circuits.
- [7] ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.
- [8] ASTM A 153-82, Standard Specifications for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.⁴
- [9] NEMA LA 1-1986, Surge Arresters.⁵

² ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

³ ANSI/IEEE publications can be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Service Center, The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

⁴ ASTM publications are available from the Sales Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

⁵ NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW Washington, DC 20037.

[10] NEMA 107-1964 (R 1981), Methods of Measurement of Radio-Influence Voltage of High-Voltage Apparatus.

4. Service Conditions

4.1 Usual Service Conditions. An arrester conforming to this standard shall be capable of successful operation under the following service conditions:

4.1.1 Physical Conditions

(1) Continuous air temperature in the general vicinity of the arrester shall be between -40°C and 40°C ⁶

(2) Temporary maximum air temperature due to external heat sources near the arrester not exceeding 60°C

(3) Altitude not exceeding 1800 m (6000 ft)

4.1.2 System Conditions

(1) Nominal power system frequency of 48 Hz to 62 Hz

(2) 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, and should be called to the attention of the manufacturer.

4.2.1 Physical Conditions

(1) Continuous air temperatures in the general vicinity of the arrester exceeding the range of -40°C to 40°C

(2) Temporary maximum air temperature due to external heat sources near the arrester exceeding 60°C

(3) Altitude exceeding 1800 m (6000 ft). Arresters for service at higher altitudes shall be suitable for operation at either of the following altitude ranges:

(a) 1801 m–3600 m (6001 ft–12 000 ft)

(b) 3601 m–5400 m (12 001 ft–18 000 ft)

(4) Exposure to:

(a) Damaging fumes or vapors

(b) Excessive dirt, salt spray or other current-conducting deposits, steam, or explosive atmospheres, abnormal vibrations or shocks

(5) Limitation on clearances to nearby con-

ducting objects, particularly at altitudes exceeding 1800 m (6000 ft)

(6) Unusual transportation or storage

4.2.2 System Conditions

(1) Nominal power frequency other than 48 Hz to 62 Hz

(2) System operating conditions whereby the ratings of the arrester may be temporarily exceeded. Some examples are:

(a) Loss of neutral ground on normally grounded circuit

(b) Generator overspeed

(c) Resonance during faults upon loss of major generation

(d) System instability

(e) Persistent single line-to-ground fault on ungrounded three-phase systems

(3) Any other unusual conditions known to the user.

5. Standard Voltage Ratings: Duty-Cycle Voltage and Maximum Continuous Operating Voltage (MCOV)

The standard rms duty-cycle voltage ratings in kilovolts and the corresponding MCOV (rms) 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	5.1	144	115
9	7.65	168	131
10	8.4	172	140
12	10.2	180	144
15	12.7	192	152
18	15.3	228	180
21	17.0	240	190
24	19.5	258	209
27	22.0	264	212
30	24.4	276	220
36	29.0	288	230
39	31.5	294	235
45	36.5	312	245
48	39	396	318
54	42	420	335
60	48	444	353
72	57	468	372
90	70	492	392
96	76	540	428
108	84	564	448
120	98	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.

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-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.

6.4 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.

6.5 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 waveshape. See 8.4.

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.

7. Test Procedures

7.1 Complete Arrester Test Specimens. New and clean arresters shall be used for each test unless specified otherwise.

7.1.1 All test specimens for arrester designs incorporating a disconnector, either as an integral part or as an accessory, shall include the disconnector.

7.1.2 The arrester shall be mounted in the position(s) in which it is designed to be used.

7.1.3 The arrester mounting bracket, if used, shall be connected to the ground terminal.

7.1.4 The grading or control ring, if used, shall be included in design tests influenced by stray capacitance effects.

7.2 Prorated Arrester Test Section. A prorated section shall accurately reproduce performance of the represented arrester for all characteristics being demonstrated by the particular test. When thermal prorating is required:

(1) The model, including porcelain, shall represent a cross section of the arrester being modeled.

(2) Housing length shall be great enough to enclose the prorated internal element(s), but shall not be more than 50% longer than the prorated internal element(s). Porcelain length in excess of 10% of the prorated internal element(s) shall be insulated both internally and externally with at least 2 in of uncompressed glass wool insulation or equivalent. The total mass of the porcelain model shall not be more than 110% of the mass of the porcelain section of the arrester being represented.

(3) Both ends of the housing shall be closed using at least 2 in of uncompressed glass wool insulation thickness or equivalent, and the insulation shall be arranged to cover the ends of the porcelain; the thermal resistivity constant (R value) of the insulation should be 5 or greater.

(4) Maximum conductor size used for electrical connections within the sample is AWG No 12 (6.53 MCM).

7.3 Test Measurements. Measurement practices shall be in accordance with:

(1) The specifications for the individual tests as given in this standard

(2) For dielectric tests, see ANSI/IEEE Std 4-1978 [7].

7.4 Impulse Test-Wave Tolerances. For all test waves in these standards, the following tolerances shall apply unless otherwise specified:

Measured Quantity	All Other	
	1.2/50 Waves	Exponential Waves
Crest value	± 3%	± 10%
Front time	± 30%	± 10%
Time to half value	± 20%	± 10%
Nominal rate of rise of wave front		± 10%

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 an approximately sinusoidal shape.

8. Design Tests

8.1 Arrester Insulation Withstand Tests. Test procedures shall comply with Section 7. The assembled insulating members of the arrester or single unit shall withstand impulse and power-frequency voltage tests between line and ground

Table 2
Insulation Withstand Test Voltages

rms Duty-Cycle Voltage Rating of Arrester (kV)	Station and Intermediate Arresters			Distribution and Secondary Arresters		
	Impulse Test 1.2/50 Full Wave (kV) Crest* (BIL)	60 Hz rms Test Voltage (kV)		Impulse Test 1.2/50 Full Wave (kV) Crest* (BIL)	60 Hz rms Test Voltage (kV)	
		1 min Dry Test	10 s Wet Test**		1 min Dry Test	10 s Wet Test**
0.175 (Indoor)	—	—	—	5	2.5	—
0.175 (Outdoor)	—	—	—	5	3.0	2.0
0.650 (Indoor)	—	—	—	10	2.5	—
0.650 (Outdoor)	—	—	—	10	6.0	4.0
1	—	—	—	30	10	6
3	60	21	20	45	15	13
6	75	27	24	60	21	20
9	95	35	30	75	27	24
10	—	—	—	75	27	24
12	110	50	45	85	31	27
15	110	50	45	95	35	30
18	—	—	—	125	42	36
21	150	70	60	125	42	36
24	150	70	60	—	—	—
25	—	—	—	150	70	60
27	—	—	—	150	70	60
30	200	95	80	150	70	60
36	200	95	80	—	—	—
39	250	120	100	—	—	—
48	250	120	100	—	—	—

* The values given apply for either positive or negative waves.

** For outdoor arresters only.

NOTE: For arresters rated at other values than those listed in column 1, the insulation tests shall be those specified for the next higher rating.