IEEE C62.1-1989
(Revision of ANSI/IEEE C62.1-1984)

IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits

Sponsor
Surge Protective Devices Committee
of the
IEEE Power Engineering Society

Approved November 9, 1989
IEEE Standards Board

Abstract: IEEE C62.1-1989, *IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Systems*, describes the service conditions, classifications and voltage ratings, design tests with corresponding performance characteristics, conformance tests, and certification test procedures for station, intermediate, distribution and secondary class arresters. Terminal connections, housing leakage distance, mounting and identification requirements are defined. Definitions are provided to clarify the required test procedures and other portions of the text.

Foreword

(This Foreword is not a part of IEEE C62.1-1989, IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits.)

This standard supersedes ANSI/IEEE C62.1-1984. In addition to a revised title and scope, there are three other substantive changes in the standard.

The title and scope are revised to clarify that the standard applies only to gapped silicon-carbide surge arresters.

The magnitude of the low current pressure-relief test currents, and the asymmetry factor of crest asymmetrical to the rms symmetrical current, were revised to harmonize with IEC standards.

A sealing system test has been added as an additional design test for distribution class surge arresters. Routine tests for distribution class surge arresters have been added, and require the manufacturer to perform the following on all arrester units:

1) Dry power-frequency sparkover test
2) Ionization voltage test
3) Leak test.

In addition to the above substantive changes, editorial changes clarify:

1) That voltage ratings of prorated sections utilized for discharge-current withstand tests for station and intermediate class arresters shall be 3 kV or more, but need not exceed 9 kV
2) The requirement for line and ground terminal of station and intermediate class arresters.

At the time this standard was published, it was under consideration for approval as an American National Standard. The Accredited Standards Committee on Surge Arresters, C62, had the following members at the time this document was sent to letter ballot:

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CLAUSE PAGE

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IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits

1. Scope

This standard applies to gapped silicon-carbide surge-protective devices designed for repeated limiting of voltage surges on 50 Hz or 60 Hz power circuits by passing surge discharge current and subsequently automatically interrupting the flow of follow current. This standard applies to devices for separate mounting and to those supplied integrally with other equipment.

2. Definitions

The following definitions apply specifically to surge arresters and do not necessarily cover other applications.

arrester disconnector: 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 power current through the arrester during disconnection generally is a function of 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 [3].[1]

certification tests: Tests made, when required, to verify selected performance characteristics of a product or representative samples thereof.

classification of arresters: Arrester classification is determined by prescribed test requirements. These classifications are:

station arrester
intermediate arrester
distribution arrester
secondary arrester

[1]Numbers in brackets correspond to those in the references listed in Section 3. of this standard.

NOTE — See 5.2 for the test requirements.

coefficient of grounding: The ratio E_{LG}/E_{LL}, expressed as a percentage, of the highest root-mean-square line-to-ground power-frequency voltage E_{LG}, on a sound phase, at a selected location, during a fault to ground affecting one or more phases to the line-to-line power-frequency voltage E_{LL} which would be obtained, at the selected location, with the fault removed.

NOTES:

1 — Coefficients of grounding for three-phase systems are calculated from the phase-sequence impedance components as viewed from the selected location. For machines, use the subtransient reactance.

2 — The coefficient of grounding is useful in the determination of an arrester rating for a selected location.

3 — A value not exceeding 80% is obtained approximately when, for all system conditions, the ratio of zero-sequence reactance to positive-sequence reactance is positive and less than 3, and the ratio of zero-sequence resistance to positive sequence reactance is positive and less than 1.

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

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 by the manufacturer 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 when sparkover occurs.

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 rating: 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.

fault-current withstand: The maximum rms symmetrical fault current of a specified duration that a failed distribution class arrester will withstand without an explosive fracture of the housing.

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.

follow (power) current: The current from the connected power source that flows through an arrester during and following the passage of discharge current.

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

grounded system: An electric system in which at least one conductor or point (usually the neutral conductor or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a grounding device.

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

impulse: A surge of unidirectional polarity.

impulse sparkover volt-time characteristic: The 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.

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 prior to the flow of discharge current.

indoor arrester: An arrester that, because of its construction, shall 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.

NOTE — When a line terminal is not supplied as an integral part of the arrester, and the series gap is obtained by providing a specified air clearance between the line end of the attester and a conductor, or arcing electrode, etc., the words line terminal used in the definition refer to the conducting part that is at line potential and that is used as the line electrode of the series gap.

maximum (highest) 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 [2].

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 C84.1-1989 [2].

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 root-mean-square 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 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.

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.

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

recovery voltage: The voltage that occurs across the terminals of a pole of circuit-interrupting device upon the interruption of the current.

NOTE — For an arrester, this occurs as a result of interruption of the follow current.

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.

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

series gap: An intentional gap(s) between spaced electrodes: it is in series with the valve element of the arrester, substantially isolating the element from line or ground, or both, under normal line-voltage conditions.

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 discharging or bypassing surge current; it prevents continued flow of follow current to ground, and 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 (circuit) voltage: The root-mean-square 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: Discharging a surge through an arrester while the arrester is energized.

valve arrester: An arrester that includes a valve element.

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.

voltage rating: The designated maximum permissible operating voltage between its terminals at which an arrester is designed to perform its duty cycle. It is the voltage rating specified on the nameplate.

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

wave shape designation (of an impulse): 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 as defined in 2.28. 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.

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

wave shape of a rectangular impulse of current or voltage: This wave is designated by two numbers. The first designates the minimum value of current or voltage which is sustained for the time in microseconds designated by the second number. An example is the 75 A · 2000 µs wave.

virtual zero point (of an impulse): The intersection with the zero 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.

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 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.
2) For voltage waves with wave front duration of 30 or more µs, 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.

3. References

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

[1] ANSI C37.42-1989, American National Standard Specifications for Distribution Cutouts and Fuse Links.[2]

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

[3] ANSI C92.1-1982, American National Standard Insulation Coordination.

[4] ASTM A 153-82, Standard Specification for Zinc Coating (Hot-Dipped) on Iron and Steel Hardware.[3]

[5] IEEE C62.2-1987, IEEE Guide for Application of Valve Type Surge Arresters for Alternating Current Systems (ANSI).[4]

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

[7] NEMA LA1-1986, Surge Arresters.[5]

[8] NEMA 107-1987, 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, at a minimum, designed for application under the following conditions:

4.1.1 Physical Conditions

1) Ambient temperature not exceeding 40 °C
2) Altitude not exceeding 1800 m (6000 ft)

4.1.2 System Conditions

1) Normal power-system frequency of 50 Hz or 60 Hz
2) System line to ground voltage within the rating of the arreste under all system operating conditions.

4.2 Unusual Service Conditions

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.

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[2] ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.
[3] ASTM publications are available from the Sales Department, American Society for Testing and Materials, 1916 Race Street, Philadephia, PA 19103.
[4] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331, or the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.
[5] NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

4.2.1 Physical Conditions

1) Ambient temperature exceeding 40 °C
2) 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-3700 m (6000 ft-12 000 ft)
   b) 3701 m-5500 m (12 001 ft-18 000 ft)
3) Exposure to:
   a) Damaging fumes or vapors
   b) Excessive dirt or other current-conducting deposits, particularly in applications where systems can operate with a grounded phase so that the arrester is at line-to-line voltage for extended periods of time
   c) Excessive humidity, moisture, dripping water, steam, or salt spray
   d) Explosive atmospheres
   e) Abnormal vibrations or shocks
4) Limitation on weight or space, including clearances to nearby conducting objects, particularly at altitudes exceeding 1800 m (6000 ft)
5) Unusual transportation or storage

4.2.2 System Conditions

1) Nominal power frequency other than 50 Hz or 60 Hz
2) System operating conditions whereby the voltage rating of the arrester may be exceeded.
   Some examples are:
   a) Loss of neutral ground on a normally grounded circuit
   b) Generator overspeed
   c) Resonance during faults upon loss of major generation
   d) System instability
3) Any other unusual conditions known to the user

5. Classification and Voltage Rating of Arresters

5.1 Voltage Ratings

The root-mean-square voltage ratings in kilovolts for arresters shall be as shown in Table 1.

5.2 Test Requirements

Arresters of the various classifications shall meet the test requirements listed in Table 2.

6. Performance Characteristics and Tests

The following tests were developed to evaluate the relative performance of arresters.

6.1 Voltage 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 and 9.1.

6.2 Power-Frequency Sparkover Test

The power-frequency sparkover tests serve to establish that the sparkover voltage at power frequency of the assembled arrester is above the rated voltage by a specified margin. See 8.2 and 9.2.

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 and 9.5.

6.4 Impulse Sparkover Voltage-Time Characteristics

The impulse sparkover voltage-time characteristics show the relation between impulse sparkover voltage and time to sparkover for a specified impulse wave shape. See 8.3 and 9.3.

6.5 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 voltage rating so that the discharge-voltage characteristics of high-voltage arresters may be determined by extrapolation. See 8.4 and 9.4.

Table 1— Arrester Voltage Ratings in kV

Secondary Arresters	Distribution Arresters	Intermediate Arresters	Station Arresters
0.175			
0.650			
	1		
	3	3	3
	6	6	6
	9	9	9
	10		
	12	12	12
	15	15	15
	18		
	21	21	21
		24	24
	25		
	27		
	30	30	30
		36	36
		39	39
		48	48
		60	60
		72	72
		90	90
		96	96
		108	108
		120	120
			144
			168
			180
			192
			240
			258
			276
			294
			312
			372
			396
			420
			444
			468
			492
			540
			576
			612
			648
			684

NOTE — Because of the more stringent requirements for protection of rotating machines, the use of arresters (all classes) rated 4.5, 7.5, 16.5, 18, 19.5, 22.5, 24, 25.5 and 27 kV is recognized for this application.

6.6 Duty-Cycle Test

The duty-cycle test serves to establish the ability of the arrester to interrupt follow current successfully and repeatedly under specified conditions. See 8.7 and 9.6.

6.7 Radio-Influence Voltage Test

The radio-influence voltage test provides a measure of the high-frequency voltage generated by an arrester that may cause objectionable communication interference. See 8.8 and 9.7.

6.8 Internal-Ionization Voltage Test

The internal-ionization voltage test provides a measure of ionization current present within an arrester design that may cause deterioration of internal arrester parts. See 8.8 and 9.7.

6.9 Pressure-Relief and Fault-Current Withstand Tests

The pressure-relief and fault-current withstand tests serve to demonstrate that failed arresters will withstand ensuing fault current under specified conditions without violent disintegration. See 8.9 and 9.8.

6.10 Contamination Tests

The contamination tests serve to demonstrate that the arrester will withstand a prescribed power-frequency voltage without sparking over under prescribed surface contamination. See 8.10 and 9.10.

6.11 Disconnector Tests

The disconnector tests serve to demonstrate that disconnectors can withstand, without operation, the arrester design tests (9.5, 9.6, and 9.10) and provide a current-time characteristic operating curve. See 9.9.

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 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

Where the design of the arrester is such that a drip loop is required in the line lead, the loop shall have a radius of approximately 4 cm (1 $^1/_2$ in.) and shall not droop more than 4 cm (1 $^1/_2$ in.) below the point where it leaves the arrester housing. From the drip loop, the line lead shall extend vertically upward. Where an arrester mounting bracket is used, the arrester shall be arranged so the line lead is opposite the point of mounting.

Table 2— Test Requirements for Arrester Classification

		Section Reference					
Arrester Classification	**Arrester Ratings (kV)**	**Duty-Cycle Tests**	**Discharge-Current Withstand Tests**	**Insulation Withstand Tests**	**Pressure-Relief Tests**	**Fault-Current Withstand Tests**	**Contam-ination Tests**
Station	3–684	8.7	8.6.1,8.6.2	8.1	8.9		8.10
Intermediate	3–120	8.7	8.6.1,8.6.2	8.1	8.9		8.10
Distribution	1–30	9.6	9.5.1,9.5.2	9.1		9.8	9.10
Secondary	0.175 and 0.650	8.7	8.6.1	8.1			

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. The applicability of the prorated section to the particular test shall be demonstrated.

NOTE — It is permissible to use different prorated section designs for different types of tests.

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, IEEE Std 4-1978 [6].

7.4 Impulse Test-Wave Tolerances

For all test waves in these standards, as determined by means of cathode-ray oscillographs, the following tolerances shall apply unless otherwise specified:

Measured Quantity	1.2/50 Waves	All Other 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 root-mean-square voltage and shall have an approximately sinusoidal shape.

8. Design Tests for Secondary, Intermediate, and Station Class Arresters

8.1 Voltage Withstand Tests of Attester Insulation

Test procedures shall comply with Section 7. unless otherwise specified. The assembled insulating members of the arrester or single unit shall withstand impulse and power-frequency voltage tests between line and ground terminals. The internal parts 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.

8.1.1 Secondary Arrester

Insulation withstand test values shall be in accordance with Table 3.

8.1.2 Intermediate and Station Arresters Less Than 60 kV Rating

Insulation withstand test values shall be in accordance with Table 3.

8.1.3 Intermediate and Station Arresters Rated 60 kV and Above

1) The 1.2/50 impulse withstand test voltage shall be the higher of:
   a) The manufacturer's published maximum 1.2/50 impulse sparkover voltage multiplied by the factor 1.42 (Note (1)), or
   b) The manufacturer's published maximum discharge voltage for a 20 000 A discharge current multiplied by the factor 1.42 (Note(1)).
2) The 10 s wet 60 Hz withstand test voltage in rms volts shall be the higher of:
   a) The manufacturer's published maximum switching surge sparkover, or
   b) The manufacturer's published maximum switching impulse discharge voltage multiplied by the factor 0.82 (Note (2)).
3) Dry 60 Hz tests are not required for this range of arrester ratings.

NOTES:

1 — The impulse factor includes an allowance for a 20% protective margin and a + 18% correction for 1800 m (6000 ft) altitude.

2 — The switching surge factor includes an allowance for a 15% protective margin, a + 18% correction for 1800 m (6000 ft) altitude, and a 0.85 multiplier relating wet switching surge withstand to wet crest 60 Hz withstand.

Table 3— Insulation Withstand Test Voltages

	Station and Intermediate Arresters			Distribution and Secondary Arresters		
		60 Hz rms Test Voltage (kV)			60 Hz rms Test Voltage (kV)	
rms Voltage Rating of Arrester (kV)	Impulse Test 1.2/50 Full Wave kilovolts Crest* (BIL)	1 min Dry Test	10s Wet Test†	Impulse Test 1.2 / 50 Full Wave kilovolts Crest* (BIL)	1 min Dry Test	10s Wet Test†
0.1 75 (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	—	—	—

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.

*The values given apply for either positive or negative waves.
†For outdoor arresters only.

8.2 Power-Frequency Sparkover and Withstand Tests of Complete Arresters

Test procedures shall comply with Section 7. unless otherwise specified. Tests shall be made on a representative number of voltage ratings of each significant variation in the design of the arrester. Ratings within + 20% of the tested rating (or + 3 kV, whichever is larger) need not be tested. The test shall show that the completely assembled arrester complies with requirements of 8.2.1. Sparkover of an external series gap without sparkover of the complete arrester shall be permissible in these tests.

NOTE — Arresters may be damaged if the applied voltage exceeds the rated voltage for too long. It is recommended that the manufacturer be consulted about a permissible test procedure.

8.2.1 Arresters with Series Gaps

Indoor types shall be tested dry and outdoor types shall be tested dry and wet. The power-frequency sparkover voltage shall be not less than:

1) For station-class arresters rated 60 kV and above, 1.35 times rated voltage
2) For all other arresters including station-class arresters rated below 60 kV, 1.5 times rated voltage.

8.3 Impulse Sparkover Voltage-Time Characteristics

Test procedures and test wave tolerances shall comply with Section 7. unless otherwise specified. Sparkover tests shall be made on a representative number of voltage ratings of complete arresters of each significant variation in design. Ratings within ± 20% of the tested rating (or ± 3 kV, whichever is larger) need not be tested.

8.3.1 Front-of-Wave Impulse Sparkover Tests

Front-of-wave impulse sparkover tests shall be made using both positive and negative polarity impulses. The prospective crest value of the test wave shall be high enough that the sparkover of the arrester occurs before 90% of the crest value of the test wave. At least five sparkovers shall be recorded for each polarity, and the highest crest value so recorded shall be reported as the maximum front-of-wave sparkover value of the test arrester. The nominal rate of rise of the front of test wave shall be as follows:

Voltage Rating (kV)	**Nominal Rate of Rise**
Less than 3	10 kV / µs
3–240	(100 / 12) kV / µs for each kilovolt of arrester rating
Above 240	2000 kV / µs

In addition, arresters that are used for the protection of rotating machinery shall be tested at a uniform rate of rise to gap sparkover in 10 ±3 µs.

8.3.2 The 1.2/50 Impulse Sparkover Test

The purpose of this test is to determine the highest standard lightning impulse voltage greater than 3 µs duration which the arrester will allow without sparkover.

For each polarity, the test procedure shall be as follows:

1) Determine the base generator charge voltage V_G., according to the method described in the following note, and record crest voltage and time to sparkover (where sparkover occurs) for each of the 20 impulses used for establishing V_G.

   NOTE — The procedure for establishing V_G is as follows: Start by applying an impulse having a prospective crest voltage somewhat lower than the expected sparkover voltage of the attester, raising the generator charge voltage in approximately 5% steps for subsequent impulses until sparkover occurs. Then apply a series of 20 impulses, decreasing the prospective crest voltage by about 5% after every sparkover and increasing the prospective crest voltage by about 5% after every withstand. V_G is the average generator charge voltage used during the series of 20 impulses.

2) Apply five impulses using a generator charge voltage not more than 1.05 V_G and record crest voltage and time to sparkover. If sparkover does not occur within 3.0 µs after the virtual zero point on each of the five impulses, raise the generator charge voltage in additional increments not greater than 0.05 V_G until a level is reached that results in sparkover within 3.0 µs after the virtual zero point on each of the five applications. The higher prospective crest voltage of either polarity required to obtain five sparkovers on five successive applications of test impulses with constant generator charge voltage shall be reported as the 1.2 / 50 sparkover of the arrester.

8.3.3 Slow-Front (Switching-Surge) Impulse Sparkover Voltage-Time Characteristics

Sparkover tests shall be made on a representative number (see 8.3) of ratings to cover the range of 60 kV and higher using the following test waves (but not necessarily in the order given) having times from zero to crest of:

1) 30 µs to 60 µs
2) 150 µs to 300 µs
3) 1000 µs to 2000 µs.

The times of half-crest values on the tail should be appreciably longer than twice the time to crest, but the exact value is not of critical importance.

For each polarity, the wave shape shall be checked with the arrester in the test circuit at a test voltage that does not cause arrester sparkover in at least one of five trials.

For each wave shape and polarity, the test procedure shall be as follows:

1) Determine the base generator charge voltage V_G according to the method described in 8.3.2, recording crest voltage and time to sparkover (where sparkover occurs) for each of the 20 impulses used for establishing V_G.
2) Apply ten impulses using a generator charge voltage of 1.2 times V_G and record crest voltage and time to sparkover.
3) Apply ten impulses using a generator charge voltage of 1.4 times V_G and record crest voltage and time to sparkover.

The highest crest value of voltage with a time duration greater than 30 µs recorded during these tests, shall be considered the maximum switching surge sparkover voltage of the test arrester.

8.3.4 Maximum Impulse Sparkover Voltage-Time Characteristic

The maximum voltage attained before sparkover is plotted against the time to sparkover for the sparkovers recorded in the tests of 8.3.1, 8.3.2, and where applicable, 8.3.3. For each of the test waves used in 8.3.2 and 8.3.3, all full waves with crest higher than the lowest sparkover recorded for that wave shall be plotted at the time to crest, using a distinctive symbol. The voltages recorded in the series of 20 impulses used to establish V_G for each test wave of 8.3.2 and 8.3.3 shall be plotted. The maximum impulse sparkover voltage-time characteristic of the test arrester is a smooth curve drawn through the maximum data points. For purposes of uniform labeling of voltage-time characteristics, the region below 30 µs may be considered the steep-front voltage (lightning) protection region, and that above 30 µs, the slow-front voltage (switching-surge) protection region.

The manufacturer's published information shall state for each arrester rating the maximum impulse sparkover for the tests of 8.3.1, 8.3.2, and 8.3.3.

8.4 Discharge-Voltage Characteristics

Test procedures shall comply with Section 7. unless otherwise specified. A cathode-ray oscillograph shall be used to record test impulses.

A sufficient number of tests shall be made to obtain a representative value of voltage for each value of current specified below, using the polarity that gives the higher voltage. If the arrester is equipped with leads, discharge voltage shall be measured at the point where the leads enter the housing.

The manufacturer's published information shall state for each arrester rating the maximum discharge voltages for the discharge-current values of 8.4.2.

8.4.1

Obtain discharge-voltage time and current-time oscillograms at 10 000 A crest value with an 8/20 wave on each design of arrester and each rating between 1 kV and 12 kV, or of prorated sections for arresters with voltage ratings above 12 kV.

8.4.2

Obtain the discharge-voltage current characteristic on each design of arrester for one voltage rating or prorated section which shall be 3 kV or greater, but need not exceed 12 kV. These characteristics are to be derived from voltage-time oscillograms using currents of 1500 A, 3000 A, 5000 A, 10 000 A, and 20 000 A crest with an 8 / 20 wave shape.

Secondary-type arresters shall be given discharge-voltage tests at currents of 1500 A and 5000 A crest with an 8 / 20 wave shape.

8.5 Switching-Impulse Discharge-Voltage Test

The general test procedures shall conform to Section 7. unless otherwise specified. This test shall be conducted for each different design of intermediate and station arresters rated 60 kV and higher.

The test shall be made on representative production specimens. The voltage rating of each test specimen shall be 3 kV or more, but need not exceed 6 kV. Repeated testing of a specimen is permissible provided the discharge voltage is not degraded by the previous operations. The test specimens shall be at room temperature before each measurement.

8.5.1 Test Circuit

A distributed constant generator, similar to that specified in 8.6.2, but with the following constants, shall be used:

Z_G = 0.75 to 1.5 Ω / kV of specimen rating
L_T = 3 to 3.5 mH / kV of specimen rating (where L_T is an added inductance connected in series between the generator and the specimen)
T_D = the time duration, T_D, shall be long enough to obtain maximum discharge voltage of the specimen

where

$$T_D = 2 \cdot \sum_{i=1}^{i=N} \sqrt{L_i C_i} \geq 2000\ \mu s$$

N = number of generator sections; must be 10 or more
E_G = the generator charge voltage in per unit of test specimen crest voltage rating as specified in 8.5.3.1.

A high impedance voltage divider as defined in 8.6.2.2 shall be used.

8.5.2 Measurements

Measure the maximum crest discharge voltage of the specimen after the specimen has conducted current for at least 30 μs, and record the generator charge voltage.

NOTE — The measurement of current may be desirable but it is not required in the evaluation of this test. The relationship of the maximum discharge voltage and current of the specimen is affected by the type of circuit and its components, as well as by the design of the specimen.

8.5.3 Test Procedure

8.5.3.1 Discharge-Voltage Range Tests

Measure the crest discharge voltage of the test specimen by increasing the generator charge voltage from 1.0 per unit of the crest voltage rating of the test specimen in increments not greater than 0.25 per unit to a generator charge voltage (which need not exceed 2.5 per unit) that demonstrates that the maximum discharge voltage of the design has been determined. At least two specimens shall be tested within each charge level. One of these specimens shall be new; the other may be one which has been tested previously provided the requirements of 8.5 are met.

8.5.3.2 Discharge-Voltage Tests

At least six additional new specimens shall be tested: two specimens at approximately the generator charge voltage which produced the maximum crest discharge voltage specified in 8.5.3.1 and two each within the ± 0.25 per unit ranges of this generator charge voltage.

8.5.4 Switching Impulse Discharge-Voltage

The switching impulse discharge voltage as determined by this test shall be the average of the three highest values measured in accordance with 8.5.3.

The manufacturer's published information shall state for each intermediate and station arrester rated 60 kV and higher, a maximum switching impulse discharge voltage determined in accordance with these tests that will not be exceeded.

8.6 Discharge-Current Withstand Tests

Test procedure shall comply with Section 7. unless otherwise specified. The high- and low-current withstand tests shall be made on different specimens of the same arrester type. After the completion of the tests in 8.6.1 and 8.6.2, the test specimens shall be judged by physical condition, by the oscillograms, and by additional evaluations as specified in 8.6.1.1 and 8.6.2.1.3.

8.6.1 High-Current, Short-Duration Test

Before making the test (for intermediate and station arresters only) power-frequency sparkover (8.2) and discharge-voltage (8.4) tests shall be made on the test specimen. The discharge current shall be as specified in 8.7.3.

This test shall consist of two arrester discharges of a surge current having a 4/10 (–0%, + 50% tolerance to accommodate test equipment) wave shape, with an amplitude as specified in the following table. An oscillogram of the discharge current shall be obtained on the first discharge and an oscillogram of the discharge voltage shall be obtained on the second discharge.

Arrester Classification	Minimum Crest Current (Amperes)
Secondary	10 000
Intermediate	65 000
Station	65 000

The tests shall be made on complete arresters or on prorated sections. The voltage rating of sections tested shall be 3 kV or more, but need not exceed 9 kV.

8.6.1.1 Test Evaluations for Intermediate and Station Arresters

Following completion of test 8.6.1 for a station or intermediate arrester, the specimen shall be allowed to cool to approximately ambient temperature. Then, the power-frequency sparkover and discharge-voltage tests specified in 8.6.1 shall be repeated. Following this, the test specimen shall be subjected to the first duty cycle unit operation as specified in 8.7.3 except with power-frequency voltage adjusted to 80% of specimen rating. The test specimen shall be considered representative of an adequate design when the following criteria are met:

1) Power-frequency sparkover has not increased by more than 10% for station or 20% for intermediate arresters
2) Discharge voltage has not increased by more than 15%
3) On the duty cycle unit operation, power follow current has been interrupted
4) There is no evidence of arcing outside the gap chambers or across the valve elements and there are no broken parts.

Table 4— Values for Deriving Test Generator Constants for Transmission-Line Discharge Tests

		C_L				D_L			
						Station Arresters		Intermediate Arresters	
V_m (kilovolts)	Z_L (ohms)	micro-farads per kilometer	micro-farads per mile	E_L (kilovolts)	No. of Oper-ations	kilometers	miles	kilometers	miles
3–72	450	0.0075	0.012	2.6 V_{LG}	20	240	150	160	100
72.5–150	450	0.0075	0.012	2.6 V_{LG}	20	240	150	160	100
151–325	400	0.0088	0.014	2.6 V_{LG}	20	280	175		
326–400	350	0.0094	0.015	2.6 V_{LG}	20	320	200		
401–600	325	0.0106	0.0177	2.0 V_{LG}	20	320	200		
601–900	300	0.0112	0.0188	2.0 V_{LG}	20	320	200		

NOTE — The switching surge duty on arresters applied to cable circuits may be evaluated by the line discharge test circuit modified to take into account the capacitance, surge impedance, length and charge voltage of the cable.

8.6.2 Low-Current, Long-Duration Test

This is a transmission-line discharge test for station and intermediate arresters. There is no test required for secondary arresters.

8.6.2.1 Transmission-Line Discharge Test for Station and Intermediate Arresters

The tests shall be made on complete arresters or prorated internal sections. The voltage rating of the test specimens shall be 3 kV or more, but need not exceed 6 kV. The test shall consist of subjecting the test specimen to a series of operations as shown in Table 4. These shall be applied in groups of five consecutive operations with a maximum time interval between consecutive operations of 1 min and with not less than 1 min or more than 15 min between groups. One oscillographic record each, of the discharge voltage and the discharge current, through the test specimen, shall be made sometime during the first two and sometime during the last two operations of the series. Current and voltage records need not be made simultaneously.

8.6.2.1.1 Preparation for Tests

Before making the test described in 8.6.2.1, power frequency-sparkover (8.2) and discharge-voltage (8.4) tests shall be made on the test specimen. The discharge current shall be as specified in 8.7.3.

8.6.2.1.2 Test Circuit

The constants of a distributed constant generator, Fig 1, used in making the discharge test shall be based on the following transmission-line characteristics.

D_L = transmission-line length
V_M = maximum system line-to-line rms voltage
V_{LG} = maximum system line-to-ground voltage, crest
E_L = transmission-line charge voltage, dc
Z_L = transmission-line surge impedance
C_L = transmission-line capacitance per unit length

The values shown in Table 4 shall be used in deriving the constants of a test generator.

The constants of the test generator shall be derived as follows:

Prorating factor

$$K = \frac{\text{rms arrester rating in kilovolts}}{\text{rms specimen rating in kilovolts}}$$

Generator charge voltage in kilovolts dc

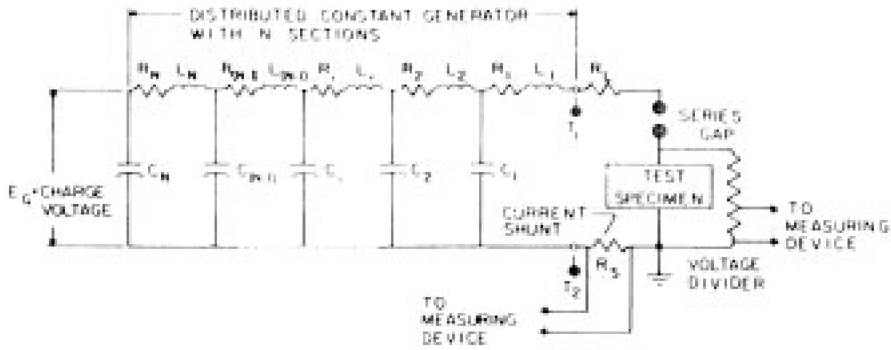
$$E_G \geq E_L / K$$

Generator surge impedance in ohms

$$Z_G \leq Z_L / K$$

Total generator inductance in microhenries

$$L_G = \sum_{i=1}^{i=N} L_i$$



R_A — OHMS RESISTANCE R_L OF LEADS FROM TEST SPECIMEN TO TERMINALS T_1 AND T_2, + R_S
R_S — OHMS RESISTANCE OF CURRENT SHUNT
R_i — OHMS SECTION RESISTANCE
C_i — μF SECTION CAPACITANCE
L_i — μH SECTION INDUCTANCE

Figure 1— Transmission-Line Discharge Test Generator and Setup

Total generator capacitance in microfarads

$C_G \geq KD_L C_L$

Total L_G $C_G \geq (Z_L\ C_L D_L L_L)^2$

Number of generator sections $N \geq 10$

Generator section requirements, designated by the subscript *i* (see Fig 1)

The resistance, in ohms, of the i^{th} generator section is denoted by R_i

(This is the measured value that depends on the resistance of the section elements and connections.)

Generator connecting lead resistance plus current shunt resistance in ohms (see Fig 1).

$R_A = R_L + R_s$

(This is a measured value.)

Generator section capacitance $C_i \leq 0.1 C_G$ (As a first approximation this is C_G divided by the number of sections chosen, but the values in each section may be modified as shown below).

Generator section surge impedance in ohms

$$Z_i = \sqrt{L_i / C_i}$$

(As a first approximation $Z_i = Z_G$, but the sections may be modified as shown below.)

To determine the exact values of capacitance C_j and surge impedance Z_j for a particular section j, the following requirements shall be met:

$$Z_j + R_A + \sum_{i=1}^{i=j} R_i = Z_G \pm 5\%$$

If $R_A + \sum_{i=1}^{i=N} R_i$ is less than 0.05 Z_G, then the first approximations for C_i and Z_i and the Li are correct. C_i may be C_G divided by the number of sections, Z may be equal to Z_G , and

$$Z_i = \sqrt{L_i / C_i}$$

If $R_A + \sum_{i=1}^{i=N} R_i$ is greater than 0.05 Z_G, Z_i

shall be adjusted section by section to agree with the given equation, that is, for the third section

$Z_3 + R_A + R_1 + R_2 + R_3 = Z_G \pm 5\%$;

for the fifth section

$Z_5 + R_A + R_1 + R_2 + R_3 + R_4 + R_5 = Z_G \pm 5\%$

The surge impedance of the sections may be adjusted by adjusting L or C provided that:

Total $C_G \geq K D_L C_L$

and

Total $L_G C_G \geq (Z_L C_L D_L)^2$

The time duration in microseconds T_D of the initial surge of the generator, as measured by an oscilloscope, can be checked by

$T_D = 2 Z_L C_L D_L$

The voltage divider used to measure the voltage of the test specimen shall have an impedance of at least 100 times the minimum impedance of the test specimen during discharge.

If an auxiliary impulse generator is used to initiate the discharge of the distributed constant generator, the stored energy of the auxiliary impulse generator shall not exceed 0.5% of the stored energy of the distributed constant generator.

8.6.2.1.3 Test Evaluation

Following the tests, the specimen shall be allowed to cool to ambient temperature. Then the tests specified in 8.6.2.1.1 shall be repeated, after which the test specimen shall be subjected to the first duty-cycle operation as specified in 8.7.3.

1) The discharge voltage and the power-frequency sparkover voltage of the test specimen shall not have increased by more than 10% above the values measured as specified in 8.6.2.1.1.

2) The test specimen shall be capable of interrupting power follow current in the duty-cycle test.

The transmission-line discharge capacity of a designated arrester rating shall be considered to have met the requirements of this standard when tests have been made in accordance with this standard and the following conditions are met:

1) The transmission line length D_L used in deriving the constants of the test generator 8.6.2.1.2 is equal to or greater than the length of line specified in Table 4.
2) Either:
   a) for the same system voltage, the rating of the designated arrester is equal to or greater than the rating of the arrester on which the test was based; or
   b) the designated system voltage is less than the system voltage on which the test was based.

8.7 Duty-Cycle Tests

Test procedures shall comply with Section 7. unless otherwise specified. Duty-cycle tests shall be made on one voltage rating of an arrester or on a prorated section. The voltage rating shall be not less than 3 kV. It need not exceed 12 kV, or a rating in kilovolts equal to $^1/_4$ the available test circuit power in megavolt-amperes, whichever is lower.

8.7.1 Preparation for Tests

Before making the tests described in 8.7.3 and 8.7.4 power frequency sparkover (8.2) and discharge-voltage (8.4) tests shall be made on the test specimen. The discharge current shall be as specified in 8.7.3

8.7.2 Test Circuit

The arrester or prorated section shall be connected across a power supply having a frequency within the range of 48 Hz to 62 Hz. The power source shall have a symmetrical rms short-circuit capacity not less than 20 MVA and a symmetrical rms short-circuit current not less than 4000 A. The crest value of power-frequency voltage, measured at the arrester terminal, shall be not less than, but as close as practical to the crest value of the rated voltage of the test specimen during and after the flow of follow current. The increase in open-circuit voltage above arrester rating should be limited to that required to ensure that rated voltage is applied to the test specimen during follow current flow. The voltage rise is allowed only to permit use of test equipment of reasonable power capacity and shall not be taken as justification for exceeding the rated voltage of arresters in service.

8.7.3 Duty-Cycle Test Procedure

The test shall consist of twenty-four unit operations with a maximum time interval between unit operations of 1 min. The initiating surge shall be an 8/20 current wave of constant polarity and of crest value as shown in the following table.

Arrester Classification	Impulse Crest Value–Amperes
Secondary arresters	1500
Intermediate arresters	5000
Station arresters	10 000

For the first unit operation, the initiating test impulse shall be timed to occur 30° after voltage zero in the half cycle of power-frequency voltage of the same polarity as the impulse. This timing shall be retarded by 30° for the second (60° after voltage zero), and by an additional 30° for each subsequent unit operation through the twelfth (at 360°). For the thirteenth unit operation, the initiating test impulse shall be timed to occur 15° after voltage zero in the half cycle of power-frequency voltage of the same polarity as the impulse. This timing shall be retarded by 30° for the fourteenth and by an additional 30° for each subsequent unit operation through the twenty-fourth (at 345°). The power-frequency voltage and current during follow current flow shall be determined.

8.7.4 High Discharge-Current Duty-Cycle Test Procedure

This test is applicable only to arresters applied on 550 kV and 800 kV systems and is performed in addition to the duty cycle test of 8.7.3. Early impulse timing and late impulse timing tests shall be made on different specimens of each arrester. The tests shall consist of two unit operations with a maximum time interval between unit operations of 10 min. The initiating surges shall be an 8/20 current wave of constant polarity and a crest current as specified below:

Maximum System Voltage	Impulse Crest Current-Amperes
550 kV	15 000
800 kV	20 000

1) *Early Timing Test*. For the first unit operation, the initiating impulse shall be timed to occur 30° after voltage zero in the half cycle of the same polarity as the impulse. The timing shall be retarded 180° for the second operation (30° after voltage zero in the half cycle of opposite polarity).
2) *Late Timing Test*. For the first operation, the initiating impulse shall be timed to occur 60° after voltage zero in the half cycle of the same polarity as the impulse. The timing shall be retarded 180° for the second operation (60° after voltage zero in the half cycle of opposite polarity).

8.7.5 Test Evaluations

Following the duty-cycle test, the specimen shall be allowed to cool to approximately ambient temperature. The tests specified in 8.7.1 shall then be repeated. The design shall be considered adequate when

1) Power-frequency sparkover has not increased more than 10%
2) Discharge voltage has not increased more than 10%
3) There is no evidence of arcing outside the gap chambers or across the valve elements, or broken parts.

NOTE — There are no restrictions on decreases of sparkover or discharge voltages. The + 10% values are arbitrary and may be modified by future experience.

8.8 Internal-Ionization Voltage and Radio-Influence Voltage (RIV) Tests

The equipment and general methods shall be in accordance with NEMA 107-1987 [8].

8.8.1 Test Specimens

The preparation and mounting of the specimens shall be in accordance with Section 7. unless otherwise specified. The test specimen shall be dry and at approximately room temperature.

When the arrester consists of a single unit, the tests shall be made on the complete arrester in its operating condition. However, when the arrester consists of a series of units, tests shall be made on combinations of units comprising a complete arrester. In effect, the tests shall be made on only a sufficient number of ratings to establish radio-influence or internal-ionization voltages over the range of arrester ratings.

8.8.2 Additional Shielding

For internal-ionization voltage tests, additional shielding of external parts is allowable as long as the inherent internal voltage grading is not affected by the external shielding. Where such shielding is not used, the radio-influence and internal-ionization voltage tests may be combined.

8.8.3 Test Procedures

The RIV and ionization voltage shall be measured at a frequency of 1.0 MHz or as near that frequency as is practicable.

Prior to making the tests, the ambient ionization voltage shall be determined by the

identical setup for determination of the internal-ionization and radio-influence voltage, but by applying the specified power-frequency test voltage without the arrester connected.

In such cases where it is found that the internal-ionization or radio-influence voltage decreases after the power-frequency test voltage has been applied for a minimum of 10 s, the arrester shall be pre-excited for a period not exceeding 5 min.

To determine the radio-influence or internal-ionization voltage, apply to the arrester terminals a test voltage equal to 1.05 times the maximum phase-to-ground operating voltage to which the arrester is to be applied.[6]

8.9 Pressure-Relief Tests for Station and Intermediate Arresters

All station and intermediate arresters shall be equipped with pressure-relief devices and tested in accordance with this standard. General test procedures shall conform to Section 7. unless otherwise specified. The high-current and low-current tests shall be made on different specimens of the same arrester type.

8.9.1 Test Specimens

The high-current test shall be made on the highest voltage rating of a complete single arrester unit of a given type and design. Low-voltage units of the same type and design need not be tested unless the lower-voltage unit is required to withstand a higher current. The test on high-voltage arresters, comprised of several individual units in series, need only be made on the highest voltage rating of an individual unit. The low-current test may be made on any voltage rating of a single unit of a given type and design.

8.9.1.1 Test Specimen Preparation

The gaps of test specimens may be reduced in spacing or shorted with a fuse wire. Valve elements may be externally fused with a wire that follows the contour of the elements in close proximity to the surface. The fuse wire used for the high-current test shall melt within a time corresponding to 30° after current initiation.[7] The fuse wire for the low-current test may be of any convenient size (see 8.9.4(4)).

[6] American National Standard test levels for RIV and internal-ionization voltage have not been established. NEMA LA1-1986 [7].
[7] On a basis of a sine wave cycle at supply frequency.

8.9.1.2 Test Specimen Mounting

The test specimen shall be mounted to simulate service conditions. The upper end shall be terminated with the base of another unit of the same arrestor design or the terminal cap, whichever is the more restrictive to pressure relief. The base of the test specimen shall be mounted on a pedestal at least 305 mm (12 in) high. An enclosure, the height of the pedestal, shall concentrically encircle the specimen. The diameter of the enclosure shall be equal to the specimen diameter plus twice the specimen height, with a minimum diameter of 1.8 m (6 ft).

8.9.2 High-Current Pressure-Relief Rating

Station and intermediate arresters shall be given a symmetrical rms high-current pressure relief rating. Compliance with these ratings shall be demonstrated by the design tests specified in 8.9.3.

8.9.3 High-Current Pressure-Relief Test Procedure

Several alternate procedures are given for demonstrating the compliance of arrester high-current pressure-relief venting with the rating class.

8.9.3.1 General Requirements

The following general requirements apply to all of the several methods of making the high-current pressure-relief tests:

1) The test circuit power frequency shall be between 48 Hz and 62 Hz.
2) For intermediate arresters, the minimum test current duration shall be 0.2 s.
3) For station arrester ratings 3 kV through 72 kV, the minimum test current duration shall be 0.2 s.
4) For station arrester ratings above 72 kV, the minimum test current duration shall be 0.1s.
5) The maximum time for the arrester to vent shall be 0.085 s.
6) The high test current shall be measured at the crest of the highest asymmetric current loop while the current is through the arrester.[8]

Table 5— Pressure-Relief Test Currents for Station and Intermediate Arresters

	Symmetrical rms Amperes	
	High Current	**Low Current**
Station 3–15 kV ratings *	65 000 or 25 000	600±200
21–684 kV ratings †	40 000 or 25 000	600±200
Intermediate 3–120 kV ratings*	16100	600±200

NOTE — it is permissible to determine the prospective currents by making the bolted fault test with reduced excitation on the generator. (This reduces the duty on the test equipment.) The short-circuit currents and the open-circuit voltage, E_R, with the reduced excitation shall be measured. The prospective currents of the test circuit are the measured short-circuit currents multiplied by E_T/E_R.

*Test values for arresters with porcelain tops have not been standardized.
†For applications requiring currents above 40 kA, ratings of 45, 50, 55 or 60 kA shall be used.

[8] The current in an arc over the exterior of an arrester may be higher than the current through the arrester for those arresters that transfer the arc to the outside. An external arc does not contribute to pressure inside of an arrester, so the current in the external arc is not a measure of test severity.

8.9.3.2 Tests at Full Voltage

Tests at full voltage should be made whenever test facilities permit this test procedure.

1) The open-circuit voltage E_T of the test circuit shall be not less than 77% of the rating of the arrester tested. (This corresponds to the normal phase-to-ground voltage on a circuit to which a 75% arrester can be applied.)
2) The impedance of the test circuit shall be adjusted to produce not less than the symmetrical rms fault current of the pressure-relief rating of the arrester (Table 5), with the arrester replaced by a bolted fault. The adjustment of the current shall be verified by measuring the symmetrical and completely asymmetrical short circuit currents of the circuit. These currents shall be termed the prospective currents of the circuit.
3) The current shall be initiated as close as possible to voltage zero, with a permissible deviation from zero to 20° after zero.[9]
4) The *X*/*R* ratio of the test circuit, without the arrester connected, shall be a minimum of 15. The ratio of the complete asymmetrical to the symmetrical rms currents for this X/R ratio is 1.55. This corresponds to a ratio of the crest asymmetrical current to the rms symmetrical current of 2.5.
5) The test on the arrester shall be made with the circuit adjusted in accordance with 8.9.3.2 (1), (2), (3), and (4). Fault current limitation by the arrester is permissible provided that other criteria for a successful test described in 8.9.5 are met. External flashover of the arrester as a result of pressure-relief venting is permissible at any time during the test.

8.9.3.3 Compensated Tests at Reduced Voltage

Where test stations capable of making full-voltage tests on high-voltage arresters are not available, tests at less than full voltage are necessary. The compensated reduced-voltage tests are for those arresters which exhibit considerable arc resistance during fault current flow through the arresters. Experience has shown that the resistance of arcs inside of arresters, generally, is not high enough to appreciably increase the impedance of the circuit and thereby limit the symmetrical current through the arrester. However, arc resistance can cause a considerable reduction in the X/R ratio of a circuit and thereby reduce the current asymmetry which can be obtained.

The general procedure in the compensated reduced-voltage test is to make a test on a rating which can be tested at full voltage to determine the current which will flow through the arrester. The test on the higher voltage rating is then made, adjusting the test circuit so as to obtain the same crest asymmetrical current, and not less than the same symmetrical current, through the low-voltage unit.

1) The arrester tested at full voltage shall be of the same type and design as the high-voltage arrester to be tested
2) The procedure for the full-voltage test is the same as described in 8.9.3.2. In this case, it is imperative to obtain an oscillographic record of the current through the arrester
3) The test on the high-voltage rating shall be made by adjusting the test circuit so as to obtain the same crest magnitude for the first current wave as was obtained during the full-voltage test on the lower rating
4) Test circuits adjusted to comply with (3) will often produce a higher symmetrical current through the high-voltage rating than was obtained during the full-voltage test on the lower rating. This higher symmetrical current may impose a more severe pressure-relief venting duty. It is permissible to synthetically reduce current, not less than $2^1/_2$ cycles after current initiation, to the symmetrical magnitude measured during the full-voltage test.

8.9.3.4 Reduced-Voltage Test

Some arrester designs having very low fault arc resistance may be tested at reduced voltage with a fault current having crest asymmetrical and rms symmetrical values not less than those specified in Table 5 and 8.9.3.2 (4). If the circuit that produces the required asymmetrical current results in higher than required symmetrical value, the current may be synthetically reduced, not less than $2^1/_2$ cycles after initiation, to the required symmetrical value.

[9] On a basis of a sine wave cycle at supply frequency.

8.9.4 Low-Current Pressure-Relief Test Procedure

The low-current pressure-relief test shall be conducted in accordance with the following on arresters of all high-current pressure-relief ratings. Since there are no variations in low-current rating, this value need not be indicated on the arrester nameplate.

1) The test circuit power frequency shall be between 48 Hz and 62 Hz.
2) This test may be made at any test circuit voltage which will provide the current specified.
3) The rms current for the low-current test may be between the limits of 600 ± 200 A. The current shall be the average for the duration of current flow.
4) The test current duration, measured from the time that the fuse wire melts, shall be until venting occurs. Maximum time to vent shall be 1 s.
5) Test current initiation may be at random with respect to the power-frequency voltage waves.
6) Any convenient value of X / R may be used for the low-current test circuit.

8.9.5 Test Evaluation

Conformance of the test specimen with this standard shall be judged from the oscillograph recordings showing test current magnitude and duration, from the evidence of the time at which venting occurred, and from the confinement of all components of the specimen within the enclosure specified in 8.9.1.2. Fracture of the housing by thermal shock shall, in itself, not constitute a failure of the specimen to pass the test.

8.10 Contamination Tests

The general test procedures shall conform to Section 7. unless otherwise specified. These tests demonstrate the ability of arrester internal gap structures to withstand the electrical stresses caused by contamination on the arrester housing. The tests shall be made on the highest voltage rating of each type and design of station and intermediate arresters. Conformance to this standard of the highest voltage rating shall also be considered substantiation of conformance of lower voltage ratings of the same arrester type and design.

8.10.1 Power-Frequency Test Voltage source

The power-frequency test voltage source and the method of measurement, shall be in accordance with IEEE Std 4-1978 [6]. The regulation of the source shall be such as to maintain the specified voltage on the arrester, except for infrequent, nonconsecutive, half cycle voltage dips of no more than 5% during leakage current pulses.

8.10.2 Test Specimen Mounting

The arresters shall be tested completely assembled as they are intended to be used in service.

8.10.3 Contaminant Preparation

The contaminant shall be mixed at least one-half hour before it is to be used and shall be stored in a container so that it can be thoroughly agitated just prior to application. The contaminant shall consist of a slurry of:

1) Water
2) Bentonite, 5 g/L of water
3) An undiluted nonionic detergent consisting of nonyl-phenyl-polyethyleneglycol-ether or other comparable long-chain nonionic esters, 1 g/L of water
4) Sodium Chloride

The volume resistivity of the slurry can be adjusted by the addition of sodium chloride.[10] Volume resistivity shall be measured at a temperature of 25 °C ± 5 °C with a low-voltage conductivity bridge.

[10] There is insufficient field experience correlating with laboratory data to permit establishment of a single standard volume resistivity of the slurry at this time. Volume resistivity must be sufficiently low to cause surface scintillation, but should not be less than 400Ω cm.

8.10.4 Contaminant Application

The arrester housing shall be clean, dry, and at theambient temperature, before the contaminant coating is applied. Washing with a detergent may be necessary to remove oil films, but the detergent should be thoroughly rinsed off with water before the arrester is dried and coated with the contaminant.

All porcelain surfaces of the arrester housing, including the undersides of all skirts, shall be completely coated. The coating shall be applied heavily enough to form drops of the slurry on the skirts of the housing. (Too much contaminant cannot be applied; the excess merely runs off.)

After each series of tests, the arrester may be washed and dried before another coat of contaminant is applied or the coating may be applied over the previous coating.

NOTE — The contaminant coating may be applied by dipping, spraying, or flow-coating. Small arresters may be conveniently coated with a paint spray gun. Large arresters may require special racks for mounting the spray or flow-coat nozzles.

8.10.5 Test Procedure

The test shall be started within 3 min after the arrester has been coated with the contaminant.

The basic test cycle shall consist of raising the voltage applied to the arrester to 80% of the voltage rating of the arrester, holding this voltage for 60 s, then raising the applied voltage to the rated voltage of the arrester and holding this voltage for 1 s, and then again reducing the voltage to 80% of the rated voltage of the arrester and the start of the next cycle. The changes in voltage shall be made as rapidly as possible but without causing any transient voltage to be applied to the arrester.

An alternate method of complying with the basic requirement is to raise the applied voltage from 80% to 110% of the rated voltage of the arrester in a time period of 3 s minimum and 9 s maximum, and then immediately reduce the voltage to 80% of the rated voltage of the arrester and start the next test cycle. If sparkover or flashover of the arrester occurs at any voltage above the rated voltage, the applied voltage shall be removed and the next test cycle started immediately.

A series of eight consecutive test cycles shall be run after which the test shall be stopped and a fresh coating of contaminant applied to the arrester. Four series of eight cycles each shall constitute a complete test.

If the external flashover of the arrester occurs at or below rated voltage during a test cycle, attempts to perform the test cycle shall be made at about 1 min intervals until a cycle has been successfully performed. The cycles during which the flashovers occurred at or below rated voltage shall not be considered as part of the test series.

8.10.6 Test Evaluation

The arrester shall be considered to have passed this test if it has not sparked over at or below rated voltage at any time during the test. It sparkover of the arrester does occur above rated voltage, it is not to be considered in the test evaluation.

For purposes of this test, a sparkover is considered to have occurred if the current from the test circuit passes through all of the gaps and valve elements of the arrester for a fraction of a half-cycle or longer.

NOTE — Arrester sparkover can be determined from the record of applied voltage for most laboratory circuits. Arrester sparkover frequently results in an almost complete collapse of the applied voltage which persists until the test circuit is de-energized. On test circuits of low impedance, arresters will sometimes sparkover, conduct current for a fraction of a cycle, and then recover. Applied voltages will not collapse completely. Under this condition, it is recommended that arrester current be instrumented to detect sparkover.

9. Design Tests for Distribution Class Surge Arrester

9.1 Voltage Withstand Tests of Attester Insulation

Test procedures shall comply with Section 7. unless otherwise specified. The assembled insulating members of the arrester or single unit shall withstand impulse and power-frequency voltage tests between line and ground terminals in accordance with Table 3. The internal parts 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.

9.2 Power-Frequency Sparkover and Withstand Tests of Complete Arresters

Test procedures shall comply with Section 7. unless otherwise specified. Tests shall be made on a representative number of voltage ratings of each significant variation in the design of the arrester. Ratings within ± 20% of the tested rating (or ± 3 kV, whichever is larger) need not be tested. Indoor types shall be tested dry and outdoor types shall be tested dry and wet.

The test shall show that for the completely assembled arrester the power-frequency sparkover voltage is not less than 1.5 times rated voltage. Sparkover of an external series gap without sparkover of the complete arrester shall be permissible in these tests.

NOTE — Arresters may be damaged if the applied voltage exceeds the rated voltage for too long. It is recommended that the manufacturer be consulted about a permissible test procedure.

9.3 Impulse Sparkover Voltage-Time Characteristics

Test procedures shall comply with Section 7. unless otherwise specified. Sparkover tests shall be made on a representative number of voltage ratings of complete arresters of each significant variation in design. Ratings within ± 20% of the tested rating (or ± 3 kV, whichever is larger) need not be tested.

9.3.1 Front-of-Wave Impulse Sparkover Tests

Front-of-wave impulse sparkover tests shall be made using both positive and negative polarity impulses. The prospective crest value of the test wave shall be high enough that the sparkover of the arrester occurs before 90% of the crest value of the test wave is reached. At least five sparkovers shall be recorded for each polarity, and the highest crest value so recorded shall be reported as the maximum front-of-wave sparkover value of the test arrester. The nominal rate of rise of the test wave front shall be as follows:

Voltage Rating kV	**Nominal Rate of Rise**
Less than 3..	kV / μs
3 and greater......................................	(100 / 12) kV / μs for each kilovolt of arrester rating

In addition, arresters that are used for the protection of rotating machinery shall be tested at a uniform rate of rise to gap sparkover in 10. ± 3 μs.

9.3.2 The 1.2 / 50 Impulse Sparkover Test

The purpose of this test is to determine the highest standard lightning impulse voltage greater than 3 μs duration which the arrester will allow without sparkover.

For each polarity, the test procedure shall be as follows:

1) Determine the base generator charge voltage V_G according to the method described in the following note, and record crest voltage and time to sparkover (where sparkover occurs) for each of the twenty impulses used for establishing V_G.

   NOTE — The procedure for establishing V_G is as follows. Start by applying an impulse having a prospective crest voltage somewhat lower than the expected sparkover voltage of the arrester, raising the generator charge voltage in approximately 5% steps for subsequent impulses until sparkover occurs. Then apply a series of twenty impulses, decreasing the prospective crest voltage by about 5% after every sparkover and increasing the prospective crest voltage by about 5% after every withstand. V_G is the average generator charge voltage used during the series of twenty impulses.

2) Apply five impulses using a generator charge voltage not more than 1.05 V_G and record crest voltage and time to sparkover. If sparkover does not occur within 3.0 us after the virtual zero point on each of the five impulses, raise generator charge voltage in additional increments not greater than 0.05 V_G until a level is reached that results in sparkover within 3.0 μs after the virtual zero point on each of the five applications. The higher prospective crest voltage of either polarity required to obtain five sparkovers on five successive applications of test impulses with constant generator charge voltage shall be reported as the 1.2 / 50 sparkover of the arrester.

9.3.3 Maximum Impulse Sparkover Voltage-Time Characteristic

The maximum voltage attained before sparkover is plotted against the time to sparkover for the sparkovers recorded in the tests of 9.3.1 and 9.3.2. For each of the test waves used in 9.3.2, all full waves with crest higher than the lowest sparkover recorded for that wave shall be plotted at the time to crest, using a distinctive symbol. The voltages recorded in the series of twenty impulses used to establish $V_G$shall be plotted. The maximum impulse sparkover voltage-time characteristic of the test arrester is a smooth curve drawn through the maximum data points. The manufacturer's published information shall state for each arrester rating the maximum impulse sparkover for the tests of 9.3.1 and 9.3.2.

9.4 Discharge-Voltage Characteristics

Test procedures shall comply with Section 7. unless otherwise specified. A cathode-ray oscillograph shall be used to record the test impulses. A sufficient number of tests shall be made to obtain a representative value of voltage for each value of current and wave shape specified, using the polarity that gives the higher voltage. If the arrester is equipped with leads, the discharge voltage shall be measured at the point where the leads enter the housing.

The manufacturer's published information shall state for each arrester design the maximum discharge-voltage for each discharge-current value in 9.4.2 on each arrester voltage rating when the 8/20 wave shape is used and on only one arrester voltage rating when the 4/10 wave shape is used.

NOTE — The 4/10 wave shape provides an indication of the higher discharge voltage for a discharge current whose time to crest is faster than the 8/20 wave shape.

9.4.1

Obtain discharge-voltage-time and current-time oscillograms at 10 000 A crest value with an 8/20 wave on each design of arrester and each rating between 1 kV and 12 kV, or on prorated sections for arresters with voltage ratings above 12 kV.

9.4.2

Obtain the discharge-voltage-current characteristics on each design of arrester for one voltage rating or prorated section which shall be 3 kV or greater, but need not exceed 12 kV. These characteristics are to be derived from voltage-time oscillograms using currents of 5 000 A, 10 000 A, 20 000 A, and 40 000 A on both 4/10 and 8/20 wave shapes.

9.5 Discharge-Current Withstand Tests

Test procedures shall comply with Section 7. unless otherwise specified. The high and low current withstand tests shall be made on different specimens of the same arrester type and design. After completion of the tests in 9.5.1 and 9.5.2, the test specimens shall be judged for conformance with this standard by the applicable test evaluations. The tests shall be made on complete arresters or on prorated sections. The voltage ratings tested shall be 3 kV or more but need not exceed 9 kV.

9.5.1 High-Current, Short-Duration Test

This test shall consist of two arrester discharges of a surge current having a 4/10(-0%, + 50% tolerance to accommodate test equipment) wave shape, with an amplitude as specified in the following table. An oscillogram of the discharge current shall be obtained on the first discharge, and an oscillogram of the discharge voltage shall be obtained on the second discharge.

Arrester Type	Minimum Crest Type Current Amperes
Heavy Duty	100 000
Normal Duty	65 000

9.5.1.1 Test Preparation

Before making the test described in 9.5.1, a discharge-voltage (9.4) test shall be made on the test specimen. The discharge current for each attester type shall have the magnitude and wave shape specified in 9.6.3.1.

9.5.1.2 Test Evaluation

Following the high-current, short-duration test, the specimen shall be allowed to cool to ambient temperature. Then, the test specified in 9.5.1.1 shall be repeated, after which the test specimen shall be subjected to a dry power-frequency withstand test. A 60 Hz voltage equal to the test specimen's maximum voltage rating shall be applied for one minute followed by raising the applied voltage to 1.5 times the maximum voltage rating and then immediately reducing the voltage to zero.

9.5.1.3

The design shall be judged to conform to this standard when the test specimen meets the following conditions:

1) Sparkover does not occur at any time during the power-frequency withstand test.
2) The discharge-voltage has not increased by more than 20% above the value measured in 9.5.1.1.
3) Examination of the specimen and the voltage oscillogram reveals no evidence of puncture or flashover of the valve elements, significant damage to the series gap or grading circuit, or broken parts.

9.5.2 Low-Current, Long-Duration Tests

The tests shall consist of twenty discharges which may be divided into four groups of five discharges each. The time interval between discharges shall be 50 s to 60 s and between groups of not more than 15 min. Voltage-time oscillograms of the discharge voltage shall be recorded on the first and twentieth discharges. A current-time oscillogram shall be recorded for one discharge. The test shall be made on complete arresters or prorated sections. The voltage ratings tested shall be 3 kV or more, but need not exceed 9 kV.

The discharge current for these tests shall have an approximately rectangular wave shape, and shall be maintained at or greater than the minimum values of current for the time as specified in the following table.

Arrester Type	Minimum Surge Current Amperes	Minimum Duration Microseconds
Heavy Duty	250	2000
Normal Duty	75	2000

9.5.2.1 Test Preparation

Before making the test described in 9.5.2, dry power-frequency sparkover (9.2), discharge-voltage (9.4) and internal-ionization voltage (9.7) tests shall be made on the test specimen. The discharge current for each arrester type shall have the magnitude and wave shape specified in 9.6.3.1. The internal-ionization voltage shall be measured at 85% of the test specimen's maximum voltage rating.

9.5.2.2 Test Evaluation

Following the low-current, long-duration test, the test specimen shall be allowed to cool to ambient temperature. Then the tests specified in 9.5.2.1 shall be repeated, after which the test specimen shall be subjected to one unit operation of the duty-cycle test. The test circuit of 9.6.2 shall be used except that a reduced supply voltage is permitted as long as the crest value of the power-frequency voltage across the arrester during follow current flow does not drop below 80% of the crest value of the test specimen's maximum voltage rating. The initiating surge shall be the discharge current specified in 9.6.3.1, timed to occur at 60° after voltage zero in the half cycle of power-frequency voltage of the same polarity as the impulse. The design shall be judged to conform to this standard when the test specimen meets the following conditions:

1) The power-frequency sparkover and discharge-voltage has not increased by more than 10% above the value measured in 9.5.2.1.
2) The internal-ionization voltage has not increased by more than 50 μV above the value measured in 9.5.2.1.
3) Interruption of the power follow current occurs during the one unit operation duty-cycle test.

9.6 Duty-Cycle Tests

Test procedures shall comply with Section 7. unless otherwise specified. Duty-cycle tests shall be made on one voltage rating of an arrester or on a prorated section. The voltage rating shall be 3 kV or more, but need not exceed 12 kV.

9.6.1 Test Preparation

Before making the tests described in 9.6.3.1 and 9.6.3.2, dry power-frequency sparkover (9.2), discharge-voltage (9.4) and internal-ionization voltage (9.7) tests shall be made on the test specimen. The discharge current for each arrester type shall have the magnitude and wave shape. specified in 9.6.3.1. The internal-ionization voltage shall be measured at 85% of the test specimen's maximum voltage rating.

9.6.2 Test Circuit

The arrester or prorated section shall be connected across the power supply having a frequency within the range of 48 Hz to 62 Hz. The impedance and voltage of the power source shall be such that the crest value of power-frequency voltage, measured at the arrester terminal, shall be maintained as close as practicable to, but not less than, the crest value of the maximum rated voltage of the test specimen during the entire test duration specified in 9.6.3.1 and 9.6.3.2. Up to a 10% increase in open-circuit voltage above arrester rating will be permitted to insure that maximum rated voltage is applied to the test specimen during follow current flow. This voltage rise is allowed only to permit use of test equipment of reasonable power capacity and must not be taken as justification for exceeding the rated voltage of arresters in service.

9.6.3 Test Procedures

9.6.3.1 Heavy and Normal Duty Arresters

The test shall consist of twenty-four unit operations with a time interval between unit operations of 50 s to 60 s. The initiating surge shall be an 8 / 20 current wave of constant polarity and of crest value as shown in the following table.

Arrester Type	Impulse Crest Value Amperes
Heavy Duty	10 000
Normal Duty	5000

For the first unit operation, the initiating test impulse shall be timed to occur 30° after voltage zero in the half-cycle of power-frequency voltage of the same polarity as the impulse. This timing shall be retarded by 30° for the second (60° after voltage zero), and by an additional 30° for each subsequent unit operation through the twelfth (at 360°). For the thirteenth unit operation, the initiating test impulse shall be timed to occur 15° after voltage zero in the half-cycle of power-frequency voltage of the same polarity as the impulse. The timing shall be retarded by 30° for the fourteenth, and by an additional 30° for each subsequent unit operation through the twenty-fourth (at 345°). The power-frequency voltage and current during follow current flow shall be determined.

9.6.3.2 Heavy Duty Arresters Only

Following the test of 9.6.3.1, the specimen shall be allowed to cool to approximately ambient temperature. The specimen shall then be subjected to two unit operations with a time interval between unit operations of 50 s to 60 s. The initiating surge shall be an 8/20 current wave of constant polarity having a magnitude of 40 000 A crest.

The initiating impulses shall be timed to occur at the earliest possible angle (but not less than 30°) after power-frequency voltage zero that will consistently establish power follow current. The impulse and power-frequency voltage shall be of the same polarity on the first unit operation, but of opposite polarity on the second unit operation.

9.6.4 Test Evaluations

Following the duty-cycle test, the test specimen shall be allowed to cool to approximately ambient temperature. The tests specified in 9.6.1 shall be repeated.

The design shall be judged to conform to this standard when the test specimen meets the following conditions:

1) The power-frequency sparkover voltage has not increased by more than 15% for the heavy duty arresters or more than 10% for the normal duty arresters above the value measured in 9.6.1, and has not decreased to less than 1.5 times arrester voltage rating.
2) The discharge voltage has not increased by more than 20% for the, heavy duty arresters or more than 10% for the normal duty arresters above the value measured in 9.6.1.
3) The internal-ionization voltage has not increased by more than 50 μV above the value measured in 9.6.1.
4) Examination of the specimen reveals no evidence of puncture or flashover of the valve elements, significant damage to the series gap or grading circuit, or broken parts.

9.7 Internal-Ionization Voltage and Radio-Influence Voltage (RIV) Tests

The equipment and general methods shall be in accordance with NEMA 107-1987 [8].

9.7.1 Test Specimens

Test procedures shall comply with Section 7. unless otherwise specified. The test specimen shall be dry and at approximately room temperature.

When the arrester consists of a single unit, the tests shall be made on the complete arrester in its operating condition. However, when the arrester consists of a series of units, tests shall be made on combinations of units comprising a complete arrester. The tests shall be made on only a sufficient number of ratings to establish radio-influence or internal-ionization voltages over the range of arrester ratings.

9.7.2 Additional Shielding

For internal-ionization voltage tests, additional shielding of external parts is allowable as long as the inherent internal voltage grading is not affected by the external shielding. Where such shielding is not used, the radio-influence and internal-ionization voltage tests may be combined.

9.7.3 Test Procedures

The RIV and ionization voltage shall be measured at a frequency of 1.0 MHz or as near that frequency as is practicable.

Prior to making the tests, the ambient ionization voltage shall be determined by the identical setup for determination of the internal-ionization and radio-influence voltage, but by applying the specified power-frequency test voltage without the arrester connected.

In such cases where it is found that the internal-ionization or radio-influence voltage decreases after the power-frequency test voltage has been applied for a minimum of 10 s, the arrester shall be pre-excited for a period not exceeding 5 min.

To determine the radio-influence or internal-ionization voltage, apply to the arrester terminals a test voltage equal to 1.05 times the maximum phase-to-ground operating voltage to which the arrester is to be applied.[11]

9.8 Fault Current Withstand Tests

All arresters for which a fault current withstand rating is claimed shall be tested in accordance with this standard. Test procedures shall comply to Section 7. unless otherwise specified.

[11] American National Standard test levels for RIV and internal-ionization voltage have not been established. NEMA Standard values appear in NEMA LA1-1986 [7].

9.8.1 Test Specimen

The tests shall be made on the highest voltage rating of a complete single arrester unit of a given type and design. These tests shall be considered to substantiate conformance to this standard of lower voltage ratings of the same type and design. Tests need not be made on the lower voltage units, except where a higher current withstand capability is claimed for a lower voltage rating. The lower voltage rating must then be tested at the current withstand capability claimed.

9.8.1.1 Test Specimen Preparation

The test specimen shall be modified by one of the following methods:

9.8.1.1.1 Tests at Full Voltage (85% of Rating)

Each of the individual gap structures, or columns, may be shunted by a fuse wire, or each gap spacing be reduced so that the 60 Hz sparkover of the test specimen shall be 50% or less of the test voltage. Each valve element shall be faulted (electrically punctured) to offer a minimum resistance to the power current or shall be externally fused. When faulted by electrical puncture, the puncture shall be visible at each end and extend the length of the valve element. When externally fused, the fuse wire shall follow the contour of the valve element and be in close proximity to its surface. The fuse wire shall melt within 30 electrical degrees after current initiation. When the test is made with surge initiation of fault current, the gap structure need not be modified. Each valve element of the test specimen shall be modified by breaking away a section of the collar insulating material at least 6 mm ($^1/_4$ in) wide along the entire length of the valve element.

9.8.1.1.2 Tests at Reduced Voltage

When required to test at reduced voltage, the individual gap structures, or columns, may be shunted by a fuse wire, or each gap spacing be reduced so that the 60 Hz sparkover of the test specimen shall be 50% or less of the test voltage. The valve element shall be externally fused. The fuse wire shall follow the contour of the valve element and be in close proximity to its surface. The fuse wire shall melt within 30 electrical degrees after current initiation.

9.8.1.2 Mounting

The test specimen shall be mounted to simulate normal service conditions. The arrester shall be centrally located above a circular enclosure 305 mm (12 in) high and 1.8 m (6 ft) in diameter. The bottom of the arrester shall be at a minimum height of 1.2 m (4 ft) from the top of the enclosure. For those designs incorporating a disconnector, the ground lead size and attachment shall be in accordance with the manufacturer's published recommendations using the maximum size, stiffness and shortest length.

9.8.2 Test Procedures

The following test procedures shall apply to all tests:

1) The test circuit power frequency shall be between 48 Hz and 62 Hz.
2) The open circuit test voltage should not be less than 85% of the rating of the arrester tested. Tests at reduced voltage shall apply when conducted at test facilities which do not have sufficient capacity to test at full 85% of rating. For reduced voltage tests, the specimen shall be prepared per 9.8.1.1.2.
3) The test current, whether the prospective current of the test circuit, or the current through the test specimen, shall be initiated close to voltage crest with a maximum permissible deviation of 10 electrical degrees on either side of crest.
4) The minimum test duration for the fault current withstand claimed for the arrester shall be 0.1 s.
5) For tests at full 85% of rating, the impedance of the test circuit shall be adjusted to produce not less than the symmetrical root-mean-square fault current withstand claimed for the arrester with the specimen replaced by a bolted fault. This current shall be termed the prospective current of the circuit. For tests at less than 85% of

rating, the impedance of the test circuit shall be adjusted to produce through the specimen not less than the symmetrical root-mean-square fault current withstand claimed for the arrester.

6) For tests at full 85% of rating, the arrester specimen, as prepared in 9.8.1.1.1, shall be tested in the identical circuit used to determine the prospective current, but connected in place of the bolted fault. Where surge initiation is used, the surge shall be of sufficient magnitude to cause the modified valve elements to flashover, as indicated by the oscillographic record. The prospective current, as determined in (5), shall be considered the test current. For tests at reduced voltage, using an arrester specimen prepared as in 9.8.1.1.2, the test current shall be the actual current through the arrester as determined from oscillographic records.

9.8.3 Test Evaluation

The design shall be judged to conform to this standard from the oscillographic recordings showing test current magnitude and duration, and from the confinement of all components of the specimen within the enclosure specified in 9.8.1.2. Fracture of the housing by thermal shock shall, in itself, not constitute a failure of the arrester to pass the test.

9.9 Disconnector Tests

Test procedures shall comply to Section 7. unless otherwise specified. These tests shall be conducted on disconnectors which are designed as an integral part of the arrester, as an attachment to the arrester or as an accessory for insertion into the line or ground lead. The tests shall be made on arresters which are fitted with arrester disconnectors or on the disconnector assembly alone if its design is such that it will be unaffected by the heating of adjacent parts of the arrester in its normally installed position. The tests shall be made on each type and design of disconnector.

9.9.1 Test Specimen Preparation

The disconnector test specimen shall have no modifications made to it.

For tests on disconnectors which are affected by the internal heating of the associated arresters, the nonlinear resistors and series gaps of the arrester shall be bypassed with a bare copper wire 0.08 mm to 0.13 mm (0.003 in to 0.005 in) in diameter in order to start the internal arcing.

For tests on disconnectors which are unaffected by the internal heating of the associated arresters, the arrester, if it is used for mounting the disconnector, shall have its nonlinear resistors and series gaps shunted or replaced by a conductor of sufficient size so that it will not be melted during the test. If 5 convenient, it is permissible to conduct this test with the disconnector separated from the arrester and mounted in an appropriate fixture.

9.9.1.1 Mounting

The test specimen shall be mounted and connected in accordance with the manufacturer's published recommendations, using a connecting lead of the maximum recommended size and stiffness and the shortest recommended length. In the absence of published recommendations, the conductor shall be hard-drawn bare copper, approximately 5 mm (0.2 in) diameter and 305 mm (12 in) long, arranged to allow freedom of movement of the disconnector when it operates.

9.9.2 Test Procedures

9.9.2.1 Discharge-Current and Duty-Cycle Tests

In the case of built-in disconnectors, these tests will be made at the same time as the tests on the arrester. In the case of disconnectors which are designed for attachment to an arrester or for insertion into the line or ground lead as an accessory, the discharge current tests may be made separately or in conjunction with tests on the arrester samples. To simulate the duty-cycle test, it may be necessary to test the disconnector in series with a specific arrester. Three disconnector samples must withstand, without operating, each of the following tests, new samples being used for each different test:

1) High-Current Short-Duration Test (9.5.1)
2) Low-Current Long-Duration Test (9.5.2)
3) Duty-Cycle Test (9.6).

9.9.2.2 Contamination Tests

For any disconnector incorporated in an arrester or intended for attachment to a specific arrester design, the contamination test (9.10) shall be repeated on a specimen with the mounting bracket disconnected from ground so that all external arrester surface leakage current flows through or across the disconnector to its ground terminal. The disconnector must withstand this test without operating.

9.9.2.3 Time-Current Characteristic Test

An operation test shall be made on arrester disconnectors to determine a time-current characteristic, that is, the relation between the time in seconds and the current in rms symmetrical amperes required to cause the disconnector to operate. It is permissible for the actual operation of the disconnector to occur after the current has ceased.

Data for the time-current curve shall be obtained at a minimum of four different levels; namely, 20 A, 80 A, 200 A, and 800 A rms, ± 20%.

9.9.2.3.1 Test Circuit and Conditions

The 60 Hz test voltage shall be any convenient value that is sufficient to maintain the required current level in the arc over the arrester valve elements and to cause and maintain the arcing of any gaps upon which operation of the disconnector depends. The circuit initiation shall be timed to produce approximately symmetrical current.

Because the disconnector is not a fault-clearing device, the test circuits shall include devices with interrupting capabilities.

NOTE — One method of preparing the test circuit is to first adjust the parameters of the test circuit with the test sample shunted by a link of negligible impedance to produce the required value of current. A closing switch can be timed to close the circuit within a time corresponding to a few degrees of voltage crest to produce approximately symmetrical current. An opening device, such as a fuse or switch, may be used with provision for adjusting the duration of current through the test sample. After the test circuit parameters have been adjusted, the link shunting the test sample should then be removed.

9.9.2.3.2 Tests for Operation and Plotting of Time-Current Characteristics

For disconnectors which operate without an appreciable time delay, the current shall be maintained at the required level until operation of the disconnector occurs. At least five new samples which have not previously been subjected to any other test shall be tested at each of the four current levels. The rms value of current through each test specimen and the duration to the first movement of the disconnector shall be plotted, using time and current as coordinates. The time-current characteristic curve shall be drawn through the maximum test points.

For disconnectors which operate with an appreciable time delay, the time-current characteristic test may be made by subjecting test samples to controlled durations of current flow at each of the required levels to determine the minimum duration which will consistently result in the operation of the disconnector. Operation of the disconnector must occur in five tests out of five trials; if one disconnector fails to operate, five additional tests at the same current level and duration must result in five disconnector operations. The rms value of current through the test specimen and the applied time duration that will result in operation subsequent to termination of the current shall be plotted, using time and current as coordinates. The time-current characteristic curve shall be drawn through the established test points.

For each disconnector type tested, there must be clear evidence of effective and permanent disconnection by the device of the associated line or ground lead.

If there is any question of this, a power-frequency voltage equal to 1.2 times the rated voltage of the highest rated arrester with which the disconnector is designed to be used shall be applied for one min without current flow in excess of 1 mA rms.

9.10 Contamination Tests

Test procedures shall comply to Section 7. unless otherwise specified. These tests demonstrate the ability of arrester internal gap structures to withstand the electrical stresses caused by contamination on the arrester housing. The tests shall be made on the highest voltage rating of each arrester type and design. Conformance to this standard of the highest voltage rating shall also be considered substantiation of conformance of lower voltage ratings of the same arrester type and design.

9.10.1 Power-Frequency Test Voltage Source

The power-frequency test voltage source and the method of measurement shall be in accordance with IEEE Std 4-1978 [6]. The regulation of the source shall be such as to maintain the specified voltage on the arrester, except for infrequent, nonconsecutive, half-cycle voltage dips of no more than 5% during leakage current pulses.

9.10.2 Test Specimen Mounting

The arresters shall be tested completely assembled as they are intended to be used in service.

9.10.3 Contaminant Preparation

The contaminant shall be mixed at least one-half hour before it is to be used and shall be stored in a container so that it can be thoroughly agitated just prior to application. The contaminant shall consist of a slurry of:

1) Water
2) Bentonite, 5 g/L of water
3) An undiluted nonionic detergent consisting of nonyl-phenyl-polyethylene-glycol-ether or other comparable long-chain nonionic esters, 1 g/L of water
4) Sodium Chloride.

The volume resistivity of the slurry can be adjusted by the addition of sodium chloride.[12] Volume resistivity shall be measured at a temperature of 25 °C ± 5 °C with a low-voltage conductivity bridge.

9.10.4 Contaminant Application

The arrester housing shall be clean, dry and at the ambient temperature, before the contaminant coating is applied. Washing with a detergent may be necessary to remove oil films, but the detergent should be thoroughly rinsed off with water before the arrester is dried and coated with the contaminant.

All porcelain surfaces of the arrester housing, including the undersides of all skirts, shall be completely coated. The coating shall be applied heavily enough to form drops of the slurry on the skirts of the housing. (Too much contaminant cannot be applied; the excess merely runs off.)

[12] There is insufficient field experience correlating with laboratory data to permit establishment of a single standard volume resistivity of the slurry at this time. volume resistivity shall be sufficiently low to cause surface scintillation, but should not be less than 400 Ω cm.

After each series of tests, the arrester may be washed and dried before another coat of contaminant is applied or the coating may be applied over the previous coating.

9.10.5 Test Procedure

The test shall be started within 3 min after the arrester has been Coated with the contaminant.

The basic test cycle shall consist of raising the voltage applied to the arrester to 80% of the voltage rating of the arrester, holding this voltage for 60 s, then raising the applied voltage to the rated voltage of the arrester and holding this voltage for 1 s, and then again reducing the voltage to 80% of the rated voltage of the arrester and the start of the next cycle. The changes in voltage shall be made as rapidly as possible but without causing any transient voltage to be applied to the arrester.

An alternate method of complying with the basic requirement is to raise the applied voltage from 80% to 110% of the rated voltage of the arrester in a time period of 3 s minimum and 9 s maximum and then immediately reduce the voltage to 80% of the rated voltage of the arrester and start the next test cycle. If sparkover or flashover of the arrester occurs at any voltage above the rated voltage, the applied voltage shall be removed and the next test cycle started immediately.

A series of eight consecutive test cycles shall be run after which the test shall be stopped and a fresh coating of contaminant applied to the arrester. Four series of eight cycles each shall constitute a complete test.

If the external flashover of the arrester occurs at or below rated voltage during a test cycle, attempts to perform the test cycle shall be made at about 1 min intervals until a cycle has been successfully performed. The cycles during which the flashovers occurred at or below rated voltage shall not be considered as part of the test series.

9.10.6 Test Evaluation

The arrester shall be considered to have passed this test if it has not sparked over at or below rated voltage at any time during the test. If sparkover of the arrester does occur above rated voltage, it is not to be considered in the test evaluation.

For purposes of this test, a sparkover is considered to have occurred if the current from the test circuit passes through all of the gaps and valve elements of the arrester for a fraction of a half-cycle or longer.

NOTE — Arrester sparkover can be determined from the record of applied voltage for most laboratory circuits. Arrester sparkover frequently results in an almost complete collapse of the applied voltage which persists until the test circuit is de-energized. On test circuits of low impedance, arresters will sometimes sparkover, conduct current for a fraction of a cycle, and then recover. Applied voltages will not collapse completely. Under this condition, it is recommended that arrester current be instrumented to detect sparkover.

9.11 Sealing System Test

The test shall be performed on fully assembled units. A representative sample of each seal design shall be subjected to the test described in 9.11.2.

9.11.1 Preparation for Test

Before making the test described in 9.11.2, dry power-frequency sparkover (9.2), internal-ionzation voltage (9.7) at 85% of the specimen's maximum voltage rating and internal leakage current at maximum rated voltage shall be measured on the sample specimens.

9.11.2 Test Procedure

The sample specimens shall be subjected to the following parts of the test in the order listed.

9.11.2.1 Terminal Torquing

The terminals of each arrester shall be torqued to 20 foot-pounds.

9.11.2.2 Thermal Conditioning

The sample specimens shall be placed inside a circulating air oven and subjected to a constant 70 °C ± 3 °C temperature for 14 days, after which the specimen shall be allowed to return to room temperature.

9.11.2.3 Seal Pumping

The sample specimens shall be heated uniformly to 60 °C ± 3 °C and kept at that temperature for at least 1 h. Then the specimens shall be placed in a cold water bath that has a temperature of 4 °C ± 3 °C for not less that 2 h. The transfer time between the hot and cold media shall be no more than 5 min. The test cycle shall be performed 10 times. The cold water bath shall have a weight of water at least 10 times the weight of the sample specimens.

9.11.3 Test Evaluation

After the seal pumping portion of the test, the specimens shall be allowed to reach ambient temperature. Then the measurements specified in 9.11.1 shall be repeated, after which each specimen shall be opened for a visual inspection.

The design shall be judged to conform to this standard when the test specimens meet the following conditions:

1) The power-frequency sparkover voltage has not changed by more than 10% from the value measured in 9.11.1.
2) The internal-ionization voltage has not increased by more than 20 μV above the value measured in 9.11.1.
3) The internal leakage current has not increased by more than 10% above the value measured in 9.11.1
4) No moisture is found within the arrester specimens upon visual examination of the internal parts and surfaces.

10. Routine Tests for Distribution Class Surge Arrester

10.1 Routine Tests

The manufacturer shall perform the following tests on all arrester units. Those unit failing any of the tests shall be rejected.

10.1.1 Dry Power-Frequency Sparkover Test (9.2)

The power-frequency sparkover voltage shall not be less than 1.5 times rated voltage and within the manufacturer's specified design limits.

10.1.2 Ionization Voltage Test

The ionization voltage shall be measured at a frequency of 1.0 MHz or as near that frequency as is practical. The applied power-frequency voltage during this test shall be at least equal to 85% of the maximum voltage rating of the arrester. The permissible ionization voltage shall not exceed 50 μV. Maximum permissible background ionization voltage shall be limited to 25 μV.

10.1.3 Leak Test

The manufacturer's routine leak test shall be used and arrester units shall meet the manufacturer's requirements for that test.

11. Conformance Tests

11.1 Conformance Tests

Conformance tests as defined in Section 2. shall consist of the following:

11.1.1 Power-Frequency Sparkover Test

The test shall be made in accordance with 8.2 or 9.2, except that the test shall be made dry only.

The test shall be made on the complete arrester unless the arrester consists of a series of complete arrester units, when it may be made on the individual units.

11.1.2 Impulse Sparkover Test

The test shall be made in accordance with 8.3.1 or 9.3.1.

11.1.3 Discharge-Voltage Test

The discharge-voltage shall be determined as described in 8.4 or 9.4, using a discharge current of 8/20 wave shape with crest amplitude of not less than 1500 A. Where the option of part testing rather than tests on the complete arrester is chosen, all test waves shall have the same nominal crest and wave form within the tolerance limits of 7.4. The test shall be made utilizing any of the following options:

1) Test on the complete arrester
2) Tests on each of the individual units of the arrester
3) Tests on all of a number of unhoused prorated sections, not necessarily of the same rating, which have been assembled from the interior gap and valve elements so that:
    a) All elements have been used
    b) No element is used in more than one of the prorated sections.

For options (2) or (3) arrester discharge voltage is the arithmetic sum of the individual measurements. Oscillograms shall be made of the discharge currents and voltages.

12. Construction

12.1 Identification Data

The type and identification number shall identify the design or construction of the complete arrester. Any change in operating characteristics, design, or construction that is likely to affect the arrester application or performance shall be accompanied by a change in identification. The following minimum information shall be firmly attached to or made an integral part of each arrester:

1) Arrester classification per Section 2.

2) Manufacturer's name or trademark
3) Manufacturer's type and identification number
4) Voltage rating of the arrester
5) Setting of the external series gap, if used
6) For distribution arresters only, the year of manufacture
7) For intermediate and station arresters, the pressure-relief rating in amperes.

12.2 Standard Mountings

12.2.1 Station and Intermediate Arresters

Standard mountings shall be provided so that:

1) Arresters rated 100 kV or less shall not require bracing; arresters rated higher than 100 kV may require bracing
2) Arresters shall have provision for bolting to a flat surface
3) When required, arresters shall have provision for suspension mounting.

12.2.2 Distribution Arresters

Distribution arresters shall be so designed that they may be mounted on the mounting bracket described in ANSI C37.42-1989 [1].

12.2.3 Secondary Arresters

Secondary arresters shall be provided with hangers or brackets for mounting.

12.3 Iron and Steel Parts

Exposed iron and steel parts, excepting threaded parts 6. mm ($^1/_4$ in) and smaller, shall be coated with zinc or a material having equivalent protection against atmospheric corrosion. If coated by the hot-dip galvanizing method, the coating shall be in accordance with ASTM A 153-82 [4].

12.4 Terminal Connections

Terminal connections shall be provided as follows:

12.4.1 Station and Intermediate Arresters

Station and intermediate arresters shall be provided with solderless clamp-type line and ground terminals capable of securely clamping conductor diameters of 6 mm to 20 $^1/_4$ mm ($^1/_4$ in to $^3/_4$ in). Line terminals shall provide for both horizontal or vertical conductor entrance and ground terminals for horizontal conductor entrance only. Station arresters, except those with porcelain tops, shall also be provided with line end terminal pads with two, three, or four holes to accommodate $^1/_2$ -inch bolts, with holes spaced on 4.5 cm (1 $^3/_4$ -inch) centers arranged in a line, a right angle or a square for the two, three or four holes, respectively.

12.4.2 Distribution Arresters

Distribution arresters shall be provided with either terminals or flexible insulated leads for line, or ground connections. When terminal connectors are provided and unless otherwise specified, they shall be solderless clamp-type terminals capable of securely clamping conductor sizes from AWG No 6, solid to AWG No 2, stranded 4.1 mm to 7.2 mm (0.162 in to 0.292 in) diameter. When flexible line or ground leads are provided and unless otherwise specified, they shall be

455 mm ± 25 mm (18 in ± 1 in) long and shall have a current-carrying capability equal to or greater than that of AWG No 6 solid copper.

12.4.3 Secondary Arresters

Secondary arresters shall be provided with either terminals or flexible insulated leads for line or ground connections. When terminal connectors are provided and unless otherwise specified, they shall be solderless clamp-type terminals capable of securely clamping conductor sizes from AWG No 14 solid to AWG No 6 stranded 1.6 mm to 4.6 mm (0.064 in to 0.182 in) diameter. When flexible line or ground leads are provided and unless otherwise specified, they shall be 455 mm ±, 25 mm (18 in ± 1 in) long and shall have a current-carrying capability equal to or greater than that of AWG No 14 solid copper.

12.5 Housing Leakage Distance

Intermediate and station arresters rated from 60 kV to 684 kV shall have a minimum external leakage distance measured from energized metal parts to grounded metal parts of 25 mm (1 in) for each 1 kV rms of arrester rating.

13. Protective Characteristics

For the protective characteristics of arresters conforming to this standard, it is recommended that reference be made to IEEE C62.2-1987 [5].

14. Certification Test Procedures for Arresters Applied to Unit Substations[13]

14.1 General

The purpose of this section is to explicitly state the following:

1) The test and evaluation procedures
2) The monitoring and retest timing which are required for certification of valve type arresters with voltage ratings from 3 kV through 36 kV.

14.2 Tests

Certification tests shall consist of the following:

14.2.1 Front-of-Wave Impulse Sparkover

The test shall be made in accordance with 8.3.1 or 9.3.1 on samples specified in Table 6. Record five sparkovers of each polarity on each unit. Evaluate per 14.3.

14.2.2 Discharge-Voltage

Test using the general procedures of 8.4 or 9.4. Use the number of samples specified in Table 6, and test at the single current level listed for the appropriate classification below. Evaluate per 14.3.

[13] Certification tests are not required if the arresters are purchased by and used under the exclusive control of electric utilities.

Arrester Classification	Test Current (Amperes)
Distribution	5000
Intermediate	5000
Station	10 000

14.2.3 Duty-Cycle Tests

On three samples of any voltage rating which is 3 kV or greater, but need not exceed 12 kV, test and evaluate individual samples in accordance with 8.7 or 9.6. On this test, for each arrester class, the single voltage rating sample covers all ranges of ratings specified in Table 6. Evaluate per 14.3.

14.2.4 High-Current, Short-Duration Test

On three samples of any voltage rating which is 3 kV or greater, but need not exceed 12 kV, test using the general procedures of 8.6.1 or 9.5.1. On this test, for each arrester class, the single voltage rating sample covers all ranges of ratings specified in Table 6. After the two surges, subject each sample to a 60 Hz withstand test. Those samples which withstand their 60 Hz rated voltage for one min have passed the High-Current, Short-Duration Test for the purposes of this certification. Evaluate per 14.3.

14.3 Evaluation Procedure

14.3.1

Compare the measured maximum voltages obtained in 14.2.1 and 14.2.2 to the values for the tested arrester class and rating in Appendix A, IEEE C62.2-1987 [5]. An individual sample has passed the test if any measured voltage is not greater than the appropriate value in the referenced appendix.

14.3.2

For each range of ratings per Table 6, overall evaluation shall be on a 3 and 3 basis as follows:

1) If all samples pass, the range has passed
2) If two or more samples fail, the range has failed
3) If one sample fails, test three more
   a) If all three samples pass, the range has passed
   b) If one or more samples fail, the range has failed

14.4 Certification

The design shall be certified for these ranges of arrester ratings:

1) Which pass tests per 14.2
2) For which manufacturer's typical test data and certification are available for those Design Tests per Sections 8. and 9. which were not specifically checked in 14.2.

Table 6— Samples Required

Arrester Ratings (kV)	Sample Rating (kV)	No of Samples
3–12	9 or 10	3
15–21	18 or 21	3
24–36	27 or 30	3

14.5 Production Monitoring and Product Retest Requirements

14.5.1 General

Subsequent to certification of an arrester in accordance with this procedure, production units shall be monitored and there shall be periodic retesting to demonstrate that the certified performance capability is maintained.

14.5.2 Production Monitoring

Monitoring of production units shall be done quarterly or at shorter intervals at the discretion of the certifying agency to verify that production tests and the product design conform to those in effect at at the time the design was certified.

14.5.3 Product Retest Requirements

For each arrester class, retesting shall be initiated at the end of specific periods measured from time of certification. The periods are defined per Table 7 by elapsed time intervals or by the total number of units of each class produced, whichever comes first. Even if the number of units produced exceeds the number listed in Table 7, retest series shall not be required less than 24 months after prior tests. The tests to be performed at the end of each period are specified by paragraph number in Table 7.

Table 7— Retest Series

Arrester Classification	Units	Years	Tests Required
Distribution	500 000	5	14.2.1, 14.2.2
	1 300 000	10	14.2.3, 14.2.4
Intermediate	40 000	5	14.2.1, 14.2.2
	107 000	10	14.2.3, 14.2.4
Station	36 000	5	14.2.1, 14.2.2
	96 000	10	14.2.3, 14.2.4