C62.31™

IEEE Standard Test Methods for Low-Voltage Gas-Tube Surge-Protective Device Components

IEEE Power Engineering Society

Sponsored by the
Surge Protective Devices Committee

IEEE
3 Park Avenue
New York, NY 10016-5997, USA

8 December 2006

IEEE Std C62.31™-2006
(Revision of
IEEE Std C62.31-1987)

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Approved 15 September 2006

IEEE SA-Standards Board

Abstract: This standard applies to gas-tube surge-protective devices for application on systems with voltages, 1000 V rms or 1200 V dc.
Keywords: ac discharge current, arc current, arc voltage, backup air-gap device, breakdown, breakdown voltage, capacitance, current, discharge current, discharge voltage, dc holdover voltage, dc sparkover voltage, follow current, gas-tube surge protector, glow current, glow-to-arc transition current, glow voltage, impulse sparkover voltage, insulation resistance, longitudinal mode voltage, short circuit, transfer time, transition time, transverse mode voltage, wave shape

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Print: ISBN 0-7381-5255-2 SH95587
PDF: ISBN 0-7381-5256-0 SS95587

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Introduction

This introduction is not part of IEEE Std C62.31-2006, IEEE Standard Test Methods for Low-Voltage Gas-Tube Surge-Protective Device Components.

This standard applies to gas discharge-tubes for over-voltage protection applications on systems with operating voltages equal to or less than 1000 V rms or 1200 V dc. These protective devices are designed for limiting the voltages on balanced or unbalanced communication and on power circuits. This standard contains a series of standard test-methods for determining the electrical characteristics of these gas discharge-tube devices components.

Gas discharge tubes are used to provide over-voltage protection in electrical circuits. When the device's breakdown voltage is exceeded, its normal high impedance state changes to a low impedance state to allow conduction of the surge discharge current. After the device conducts the surge discharge current, it interrupts the flow of system follow current and returns to its high impedance state. In the event of continuing current not representing normal system conditions, the device continues to provide a low impedance path until an external bypass mechanism activates, the source of undesirable current is de-energized, or a coordinated protective current element operates. This standards test criteria and definitions provide a common engineering language beneficial to user and manufacturer of gas-tube surge-protective devices components.

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Contents

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IEEE Standard Test Methods for Low-Voltage Gas-Tube Surge-Protective Device Components

1. Scope

This standard applies to gas-tube surge-protective device components for application on systems with voltages less than or equal to 1000 V rms or 1200 V dc. These protective devices are designed to limit voltage surges on balanced or unbalanced communication circuits and on power circuits operating from direct current (dc) to 420 Hz. This standard contains a series of standard test criteria for determining the electrical characteristics of gas-tube surge-protective devices.

The tests in this standard are intended as design tests as defined in *The Authoritative Dictionary of IEEE Standard Terms* [B1][1] and provide a means of comparison among various gas-tube surge-protective device components.[2]

Gas-tube devices are used to provide over-voltage protection in electrical circuits. When the breakdown voltage of the gas tube is exceeded, the normal high-impedance state of the tube changes to a low-impedance state to allow the gas tube to conduct the surge discharge current. After the tube conducts the surge discharge current, it interrupts the flow of power follow current and returns to its high-impedance state.

This standard's test criteria and definitions provide a common engineering language that is beneficial to the user and manufacturer of gas-tube surge-protective devices.

CAUTION

Due to the voltage and energy levels employed in the majority of tests contained herein, all measurements should be considered dangerous and appropriate caution should be taken in their performance.

2. Definitions

For the purposes of this document, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standard Terms* [B1] should be referenced for terms not defined in this clause.

2.1 arc current: The current that flows after breakdown when the circuit impedance allows a current that exceeds the glow-to-arc transition current. *Syn:* **arc mode current**.

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[1] The numbers in brackets correspond to those of the bibliography in Annex A.

[2] In this standard, the term *gas tube* or *gas-tube surge-protective device component* is used when the definition of gas-tube surge arrester (see Clause 2) is intended, and the term *protector* is used when the definition of surge protector (see Clause 2) is intended. When a test applies to both protectors and surge-protective device components, the term *device* or *gas-tube device* is used alone. For the purpose of this standard, all connections to a device are by means of the terminals.

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2.2 arc voltage: The voltage drop across the gas tube during arc current flow. *Syn:* **arc mode voltage**.

2.3 back-up air gap devices: An air gap device connected in parallel with a sealed gas-tube device, having a higher breakdown voltage than the gas tube, which provides a secondary means of protection in the event of a venting to atmosphere by the primary gas-tube device.

2.4 balanced voltage limiting: The simultaneous or near simultaneous breakdown of two gas-tube surge-protective device components in response to a longitudinal (common mode) voltage.

NOTE—The two gaps are usually combined in a single, three electrode gas-tube surge-protective device component.[3]

2.5 breakdown: The abrupt transition of the gap resistance from a practically infinite value to a relatively low value. In the case of a gap, this is sometimes referred to as **sparkover** or ignition. *See also:* **sparkover**.

2.6 breakdown voltage, ac: The minimum rms value of a sinusoidal voltage at frequencies between 15 Hz and 62 Hz that results in gas-tube sparkover.

2.7 breakdown voltage, dc: The minimum dc voltage with a ramp rate (100 V/s to 2000 V/s) that will cause breakdown or sparkover when applied across the terminals of a gas tube.

2.8 current turnoff time: The time required for the gas tube to restore itself to a non-conducting state following a period of conduction. This definition applies only to a condition where the gas tube is exposed to a continuous specified dc potential under a specified circuit condition.

2.9 dc holdover: In applications where a dc voltage exists on a line, a holdover condition is one in which a surge-protective device continues to conduct after it is subjected to an impulse large enough to cause breakdown. Factors that affect the time required to recover from the conducting state include the dc voltage and the dc current.

2.10 dc holdover voltage: The maximum dc voltage across the terminals of a gas tube under which it may be expected to clear and return to the high impedance state after the passage of a surge, under specified circuit conditions.

2.11 discharge current: The current that flows through a gas tube when sparkover occurs.

2.12 discharge voltage: The voltage that appears across the terminals of a gas tube during the passage of discharge current.

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

2.14 failure: The termination of the ability of an item to perform a required function.

NOTE 1—“Failure” is an event, as distinct from “fault,” which is a state.

NOTE 2—A failure usually results in a fault state.

2.15 fault: A state causing inability to perform a required function.

NOTE 1—Inability during preventive maintenance or other planned actions, or due to lack of external resources does not constitute a fault state.

NOTE 2—A fault is often the result of a failure of the item itself, but may exist without prior failure.

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[3] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

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2.16 failure mode: A manner in which failure occurs.

NOTE—A failure mode may be defined by the function lost or the state transition that occurred.

2.17 follow current: The current from the connected power source that flows through a gas tube during and following the passage of discharge current.

2.18 gas-tube surge arrester (gas-tube surge-protective device component): A gap, or gaps, in an enclosed discharge medium, other than air at atmospheric pressure, designed to protect apparatus or personnel, or both, from high transient voltages.

2.19 glow current: The current that flows after breakdown when circuit impedance limits the current to a value less than the glow-to-arc transition current. *Syn:* **glow mode current**.

2.20 glow-to-arc transition current: The current required for the gas tube to pass from the glow mode into the arc mode.

2.21 glow voltage: The voltage drop across the gas tube during glow-current flow. It is sometimes called the glow mode voltage.

2.22 impulse sparkover voltage: The highest value of voltage attained by an impulse of a designated wave-shape and polarity applied across the terminals of a gas tube prior to the flow of discharge current. *Syn:* **surge** or **impulse breakdown voltage**.

2.23 impulse sparkover voltage-time curve: A curve that relates the impulse sparkover voltage to the time to sparkover.

2.24 longitudinal (common) mode voltage: The voltage common to all conductors of a group as measured between that group at a given location and an arbitrary reference (usually earth).

2.25 short circuit: An abnormal connection of relatively low impedance, whether made accidentally or intentionally, between two points of different potential in a circuit.

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

2.27 surge protector: A protective device, consisting of one or more surge-protective device components, a mounting assembly, optional fuses and short-circuiting devices, etc, which is used for limiting surge voltages on low-voltage (≤1000 V rms or ≤1200 V dc) electrical and electronic equipment or circuits.

2.28 transfer time: The time duration of the transverse voltage.

2.29 transition time: The time required for the voltage across a conducting gap to drop into the arc region after the gap initially begins to conduct.

2.30 transverse (differential) mode voltage: The voltage at a given location between two conductors of a group.

3. Service conditions

3.1 Normal service conditions

Gas-tube surge-protective device components and protectors conforming to this standard shall be capable of successful operation under the following conditions, which shall be specified by the manufacturer or user, as appropriate.

3.1.1 Physical conditions

- Ambient temperature range
- Atmospheric pressure range
- Humidity conditions
- Mechanical shock conditions

3.1.2 System conditions

- The frequency range (and dc, or both)
- Voltage and current under both normal and fault conditions

3.2 Unusual service conditions

The following service conditions may require special consideration in the design or application of protectors and gas-tube surge-protective device components, and should be called to the attention of the manufacturer.

3.2.1 Physical conditions

- An ambient temperature different from the normal service conditions
- Atmospheric pressure differing from the normal service conditions
- Exposure to damaging fumes or vapors, excessive dirt or current conducting deposits, excessive humidity, moisture, dripping water, steam, or salt spray and abnormal vibrations or shocks
- Limitation on weight or space, including clearances to nearby conducting objects; particularly at atmospheric pressures differing from those specified
- Non-operating conditions, such as those encountered during transportation or storage

3.2.2 System conditions

- Voltage, current, or frequency resulting in operating conditions whereby the ratings of the devices are exceeded
- Exposure to direct lightning strikes
- Any other unusual conditions known to the user

3.2.3 Radiation

Some components may contain radioactive material. Manufacturers of such components shall mark them in accordance with national regulations.

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4. Standard design test criteria

4.1 General

The design tests described in 4.3 to 4.16 provide standardized methods for making single observations of a specified property of a gas-tube surge-protective device. These properties vary from measurement to measurement making it necessary to provide statistical descriptions of the property in order to compare products. The following procedure shall be used to describe any property that has been determined to have important statistical aspects. A product sample shall be chosen in a manner consistent with the definition of design tests as provided by *The Authoritative Dictionary of IEEE Standard Terms* [B1]. A sufficient number of devices shall be tested and the characteristic in question measured as described in the applicable design test until the parameters of the underlying statistical distribution are determined within confidence limits specified by the manufacturer or user. Values relating to the product sample such as, but not limited to, mean, median, maximum, minimum, and standard deviation may then be stated.

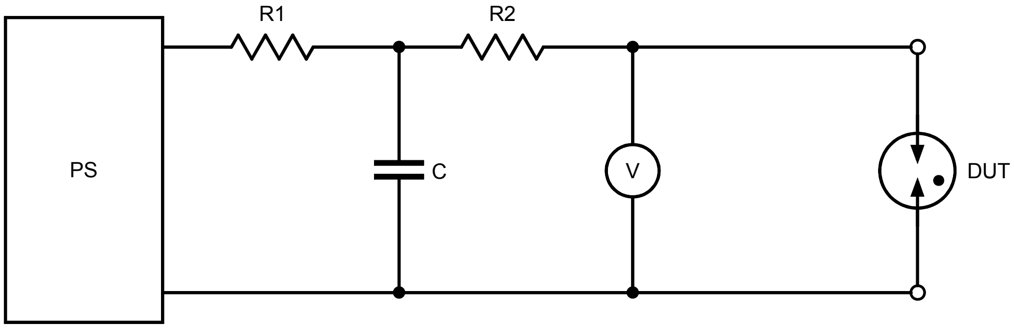
4.2 Ambient conditions

The tests described herein should be performed on devices as required by the application. Unless otherwise specified, ambient test conditions should be as follows:

Temperature	25 °C ± 5 °C
Relative Humidity	Less than 60%
Atmospheric Pressure	80 kPa to 104 kPa

4.3 DC breakdown voltage test

A representative sample of devices shall be placed in darkness for 24 h and tested in this condition using a ramp voltage waveform, with a specified voltage rate of rise, employing a suitable circuit such as that shown in Figure 1. Half of the device sample shall be tested with a positive waveform and the other half shall be tested with a negative waveform. The breakdown values shall be recorded.



C = 1 μF dc charging capacitor (non-electrolytic)
DUT = Device Under Test (gas-tube device)
PS = variable dc voltage power supply. Load ripple and current output regulation shall be < 3.0% under full power
R1 = 50 kΩ charging current limiting resistor
R2 = discharge current limiting resistor (10 Ω)
V = voltmeter or oscilloscope for observing dc breakdown voltage

Figure 1—Circuit for dc breakdown voltage test

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NOTE 1—Unless otherwise specified, a rate of rise not to exceed 2000 V/s is recommended.

NOTE 2—When dc breakdown has been sensed, the test circuit output terminals are usually shorted (by means of a crowbar circuit) to limit the duration of follow current that could otherwise flow through the device under test and potentially change the test results.

Separate tests shall be performed to determine dc breakdown voltage repeatability employing the circuit of Figure 1. A series of at least five voltage impulses of a given polarity followed by at least five voltage impulses of the opposite polarity shall be consecutively applied at intervals of less than 1 minute.

Each pair of terminals of a multigap device shall be tested separately using the test circuit of Figure 1, with the other terminal or terminals floating, unless otherwise specified.

4.4 Capacitance test

The capacitance shall be measured between each terminal and every other terminal of the device at a specified frequency. In measurements involving multi-gap devices, a three-terminal measuring instrument is required. All terminals not involved in the test shall be connected to a ground plane in the measuring instrument.

NOTE —In the absence of requirements relating to a special application, a frequency of 1.0 MHz is recommended for this test.

4.5 Insulation resistance test

The insulation resistance shall be measured from each terminal to every other terminal of the device, applying a specified dc voltage as described in Figure 2. The specified dc voltage shall be reached and held for at least 100 ms (T2 = minimum 100 ms in Figure 2), before the insulation resistance measurement is taken; also, it shall be taken before a holding time of 10 s has elapsed (T3 = maximum 10 s in Figure 2). Terminals not involved in the measurement shall be left floating.

NOTE 1—In the absence of requirements relating to special applications, 100 V dc ± 5% is suggested for testing devices with a dc breakdown voltage of 230 V or more and 50 V dc ± 5% for devices with a dc breakdown voltage below 230 V.

NOTE 2—Insulation-resistance test results may be affected by the short-circuit current of the test circuit. In the absence of requirements relating to special applications, the short-circuit current should be in the range of 8 mA–10 mA.

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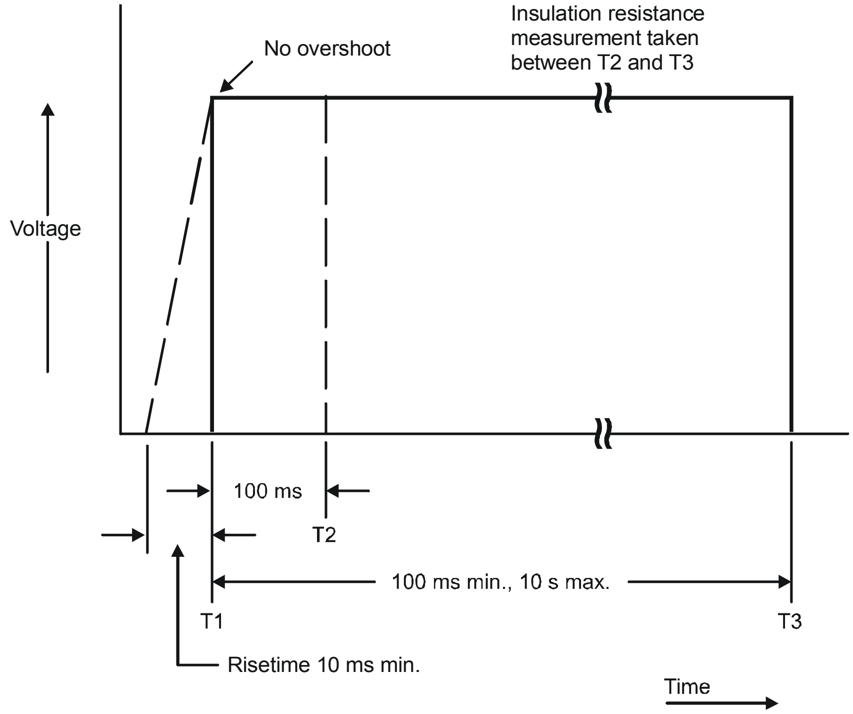

Figure 2—Voltage applied during insulation resistance test

4.6 Impulse breakdown voltage test

The purpose of this test is to determine the impulse breakdown voltage of a gas-tube protector or gas-tube surge-protective device component and to establish an impulse breakdown voltage-time curve of the device. The voltage generator used for this test must be capable of maintaining the waveform specified in Figure 3.

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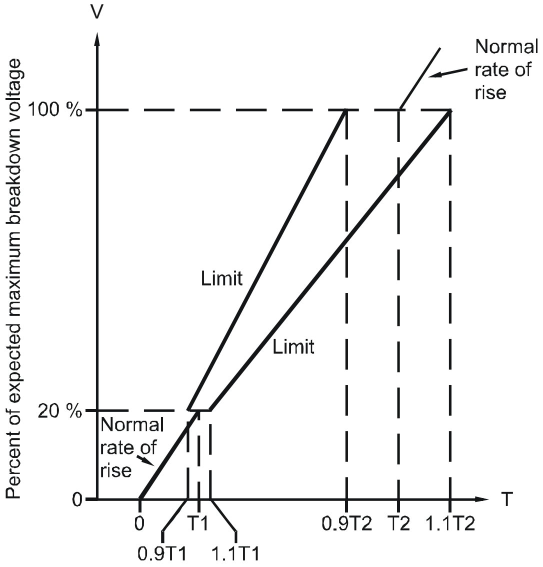
Since the intent of this test is the measurement of impulse breakdown voltage on the front of the wave, the tail of the impulse wave is unspecified. For devices with backup air gaps, see 4.17.



NOTE—Impulse breakdown test waveform (non-conducting) must be within enclosed limits.

Figure 3—Impulse breakdown test waveform

The device to be exposed to the test shall be kept in total darkness before (for at least 15 min) and during the test. Then, with a specified polarity and a ramp voltage with a specified rate of rise applied to the device, record the breakdown voltage level. To repeat the test with opposite polarity, using the same device, a minimum of 15 min shall elapse.

Discharge current should be sufficient to cause operation in the arc mode. However, operation in the glow mode during the transition into and out of the arc mode shall be permissible. Discharge current amplitude and duration should not be so high as to significantly affect repeatability of the impulse breakdown voltage test, or to consume a significant portion of device life during an impulse life test.

Separate tests shall be performed to determine the repeatability of impulse breakdown voltage. The rate of rise and crest current shall be specified. A minimum of five impulses of each polarity shall be applied at intervals of not greater than 1 min, and the breakdown voltage for each impulse shall be recorded. An additional test may be performed employing at least two applications of the impulse separated by a period greater than 24 h. Separate samples shall be employed for each of the two tests and for each rate of rise.

Each pair of terminals of a multigap device shall be tested separately with the other terminal or terminals floating unless otherwise specified.

NOTE 1—In the absence of specific requirements, discharge current should be in the range of 1 A–10 A but in any case it should be sufficient to cause operation in the arc mode. Duration of discharge current after breakdown should be as short as practicable, preferably less than 10 μs measured from 50% of peak on the leading edge to 50 % of peak on the trailing edge.

NOTE 2—In the absence of special requirements, the rates of rise should be one or more of the following linear ramp rates: 100 V/μs, 500 V/μs, 1 kV/μs, 5 kV/μs, and 10 kV/μs.

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4.7 Maximum single impulse discharge current test

The purpose of this test is to determine the ability of a device to conduct a maximum single impulse discharge current, regardless of polarity, from its line terminal to the common terminal and not fail in any of the modes described in 4.18.

The current impulse waveform may be 8/20 µs or 10/1000 µs, or both. The maximum single impulse discharge current is the peak current of the impulse. Different samples shall be tested for each polarity or waveshape. For devices with backup air gaps, see 4.17.

For multigap devices, independent maximum single impulse discharge currents of the same polarity shall be discharged simultaneously through all gaps to the common electrode.

4.8 Impulse life test

Tests shall be conducted on devices to establish a current-life characteristic based on the number of discharges to failure. Separate samples shall be used for each current waveform and each polarity tested. For devices with backup air gaps, see 4.17.

The impulse shall be determined by either of two methods

a) The impulse discharge current waveform shall be measured with the device in the circuit to ensure that the arc voltage does not affect the specified waveshape or crest current appreciably.
b) The impulse discharge current waveform shall be measured with the device replaced by a short circuit, and the open-circuit source voltage shall exceed the maximum impulse breakdown voltage of the device by not less than 50%.

Table 1—Recommended values for impulse life test

Peak current (±5%) A	Waveshape	Repetitions	Time between repetitions (min)
10; 50; 100; 200; 300; 500	10/1000	50; 100; 300; 400; 1500; 3000	2
600; 1000; 2000	10/250	5; 25	3
500; 1000; 2500; 4000	10/350	1	
2500; 5000; 10000; 20000	8/20	1; 5; 10	5

NOTE 1—In the absence of special requirements, it is recommended that insulation resistance, plus or minus dc breakdown voltage, and plus or minus impulse breakdown voltage shall be measured after each life test impulse, in that order.

NOTE 2—In the absence of special requirements, it is suggested that test value combinations be selected from the values in Table 1, e.g. 10 A, 10/1000, 1500 applications and 20000 A, 8/20, 1 application.

NOTE 3—Generally the higher current amplitudes are related with a lower number of repetitions.

For multigap devices, independent impulse life test currents of the same polarity shall be discharged simultaneously through all gaps to the common electrode.

Failure criteria for this test are defined in 4.18. The applicable failure-criteria tests shall be performed after each impulse discharge. During the impulse life test, the waiting period between breakdown voltage tests need not apply.

4.9 AC discharge current test

The device shall, for a period of time, pass 50 Hz or 60 Hz discharge current, which may be created by direct contact with a power line or by induction from a nearby power line. Many protectors contain mechanisms internal or external to the gas tube, or both, that conducts the alternating current when the conducting capacity of the gas tube has been exceeded. The purpose of this test is to determine the period of time for which protectors can conduct alternating current without activation of the safety mechanisms for various current levels. Permanent activation of these mechanisms shall be considered a fault mode.

The crest ac voltage of the source shall exceed the maximum dc breakdown voltage of the device by not less than 50%.

From the test data gathered, a root-mean-square (rms) ac load or discharge characteristic may be plotted (rms current versus time).

For multigap devices, independent ac discharge currents shall be discharged simultaneously through all gaps to the common electrode.

Failure criteria for this test are defined in 4.18. The applicable failure-criteria tests shall be performed after each ac discharge. During the ac discharge test, the waiting period between breakdown voltage tests need not apply.

Table 2—Recommended values for ac discharge current test

Current (± 5 %) A rms	Duration s	Repetitions	Time between repetitions (min)
0.5	30	1	
1	1	60	3
2.5; 5; 10; 20	1	5, 10	3
65; 130	0.183 (11 cycles)	1	
120	0.1	1	

NOTE 1—In the absence of special requirements, it is recommended that insulation resistance, plus or minus dc breakdown voltage, and plus or minus impulse breakdown voltage shall be measured after each ac discharge cycle, in that order.

NOTE 2—In the absence of special requirements, it is suggested that test value combinations be selected from the values in Table 2, e.g. 10 A rms, 1 s, 10 repetitions and 65 A rms, 11 cycles, 1 application.

4.10 Alternating follow-current test

Apply an ac source, 50 Hz or 60 Hz, with an open-circuit rms ac voltage of 25 V, 120 V, 208 V, 240 V, or 480 V (to be stated) as shown in Figure 4. The power frequency source current shall be resistance-limited to approximate unity power-factor conditions. This ac source shall have the capability to provide a follow current when conduction is initiated within the device by a secondary source of impulse current applied at thirty electrical degrees or less after the zero value of the ac source. The impulse current shall be unidirectional and of the same polarity as the applied half cycle of the ac source. The impulse should be of sufficient amplitude and time duration to ensure that the device is put into the arc mode conducting state. The maximum current, which the device will extinguish without failure, defines the maximum alternating follow-current capability. For devices with backup air gaps, see 4.17.

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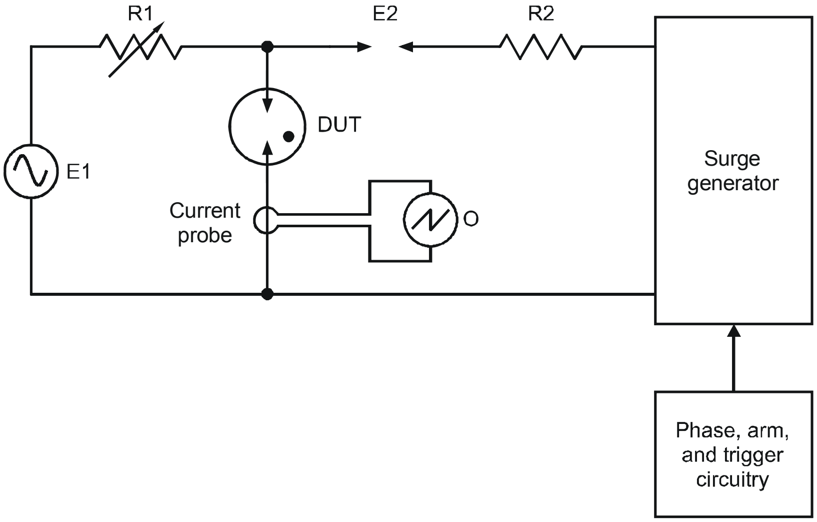
NOTE —In the absence of special requirements, it is recommended that the device be required to extinguish not later than thirty electrical degrees after the first alternating current zero crossing without failure, as specified in 4.18, and that subsequent breakdown does not occur.



DUT = Device Under Test (gas-tube device)
E1 = 50 Hz or 60 Hz source
E2 = isolation gap
O = oscilloscope or equivalent
R1 = limiting resistor
R2 = isolation resistor

NOTE 1—Reactance of 50 Hz or 60 Hz source << R1.

NOTE 2—R2 must be sufficiently large to cause prompt extinguishing of the isolation gap.

NOTE 3—Surge protection of 50 Hz or 60 Hz supply may be necessary.

Figure 4—Circuit for alternating follow-current test

4.11 DC holdover test for two-electrode devices

This test shall establish the maximum values of direct current for a given open-circuit dc voltage and specified circuit conditions that the device can extinguish. When the device is subjected to an impulse sufficient to cause the voltage across the gap of the device to drop into the arc voltage mode, the device is expected to return to its high impedance state after it has conducted the impulse current.

The current impulse that is applied to the gas tube shall be a 100 A, 10/1000 μs waveshape of the same polarity as the dc source. Three impulses shall be applied at not greater than 1 min intervals. These tests will be repeated with the test specimen connections reversed.

Tests shall be conducted, using the circuit shown in Figure 5, with the dc voltage PS1 fixed at a value to be stated. Resistor R3, in the circuit, shall be decreased from values for which no holdover is observed until holdover occurs for greater than a stated period; current IR3 shall be stated for this condition. For devices with backup air gaps, see 4.17.

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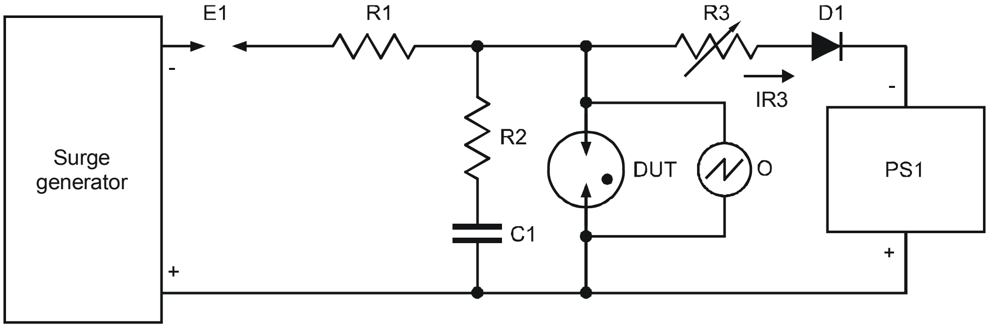
NOTE —In the absence of special requirements, it is recommended that tests be conducted with the dc voltage of PS1 fixed at 52.5 V with IR3 set for 260 mA or 135 V with IR3 set for 200 mA, or both (to be stated), and that a maximum time for current turnoff of 150 ms be employed. The R2, C1 network is applied for the 135 V, 200 mA test.



C1 = optional capacitor for simulating application conditions (0.083 µF to 0.1 µF)*
D1 = diode
DUT = Device Under Test (gas-tube device)
E1 = isolation gap or equivalent device
IR3 = direct current through R3 with DUT short-circuited
O = oscilloscope or equivalent
PS1 = constant voltage dc supply or battery (transient free ±1 % for unit impulse currents from zero to full load and from full load to zero.
R1 = impulse limiting resistor or wave-shaping network
R2 = optional resistor for simulating circuit resistance (136 Ω to 150 Ω)*

* Tests may be performed with R2 and C1 deleted from the circuit, or as specified by the user.

NOTE—Values in parenthesis are recommended in the absence of special requirements.

Figure 5—Circuit for dc holdover test of two-electrode devices

4.12 DC holdover test for three-electrode devices

This test shall establish the maximum values of direct current for a given open-circuit dc voltage and specified circuit conditions that the device can extinguish. When the device is subjected to an impulse sufficient to cause the voltage across the two sides of the three-electrode gas tube to go into the arc voltage mode, the gas tube is expected to return to its high impedance state after it has conducted the impulse current.

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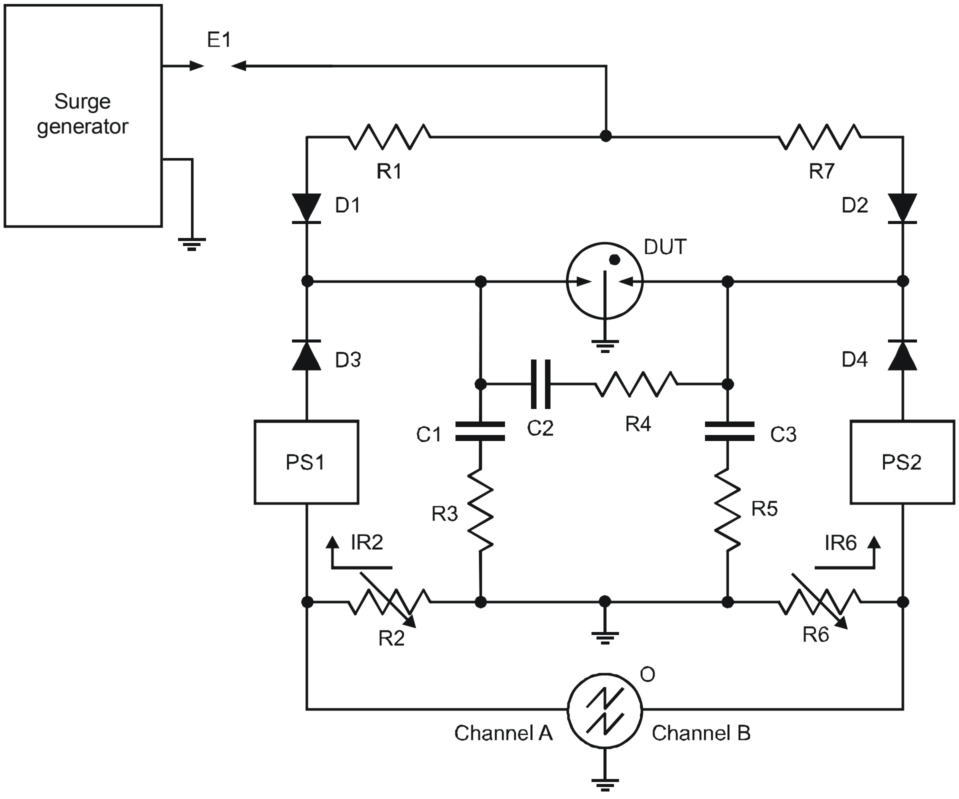
The simultaneous impulse currents that are applied to the two sides of the three-electrode gas tube shall be 100 A, 10/1000 µs waveshape. Three impulses shall be applied at not greater than 1 min intervals.



C1, C3 = optional capacitor for simulating application conditions (0.083 µF to 0.1 µF)*
C2 = optional capacitor for simulating application conditions (0.043 µF)*
D1,D2, D3, D4= diode (appropriately polarized)
DUT = Device Under Test (gas-tube device)
E1 = isolation gap or equivalent device
IR2, IR6= direct current through R2, R6 with DUT short-circuited
O = oscilloscope or equivalent
PS1, PS2 = constant voltage dc supply or battery (transient free ±1 % for unit impulse currents from zero to full load and from full load to zero.
R1, R7= impulse limiting resistor or wave-shaping network
R3, R5= optional resistor for simulating circuit resistance (136 Ω to 150 Ω)*
R4 = optional resistor for simulating circuit resistance (272 Ω)*

* Tests may be performed with R3, R4, R5 and C1, C2, C3 deleted from the circuit, or as specified by the user.

NOTE—Values in parenthesis are recommended in the absence of special requirements.

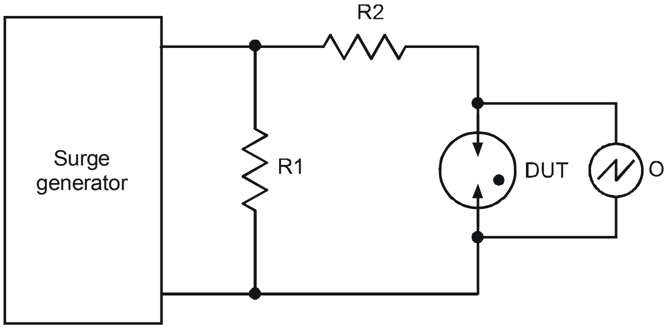
Figure 6—Circuit for dc holdover test of three-electrode devices

Tests shall be conducted, using the circuit shown in Figure 6, with the dc voltage of (PS1 and PS2 , D3, and D4) equal and fixed at a stated value with the same or opposite polarity (to be stated) applied to the terminals of the device. Resistors R2 and R6, in the circuit, shall be decreased from values for which no holdover is observed until holdover just occurs for greater than a stated period. Currents IR2 and IR6 shall be stated for this condition. For devices with backup air gaps, see 4.17.

NOTE—In the absence of special requirements, it is recommended that tests be conducted with the dc voltage of PS1 and PS2 fixed at 52.5 V with IR3 and IR6 set for 260 mA or 135 V with IR3 and IR6 set for 200 mA, or both (to be stated), and that a maximum time for current turnoff of 150 ms be employed. The R2, C1 network is applied for the 135 V, 200 mA test.

4.13 Transition time test

Transition time shall be measured in accordance with Figure 7 and Figure 8. The waveform for this test shall be 10/1000 µs. The peak impulse voltage shall be at least two times the dc breakdown voltage. The peak impulse current shall be specified and shall be between 1.5 and 4 times the glow-to-arc transition current. For devices with backup air gaps, see 4.17.



DUT = Device Under Test (gas-tube device)
O = oscilloscope or equivalent
R1 = impulse-shaping resistor
R2 = impulse-shaping and current-limiting resistor

Figure 7—Circuit for transition time test

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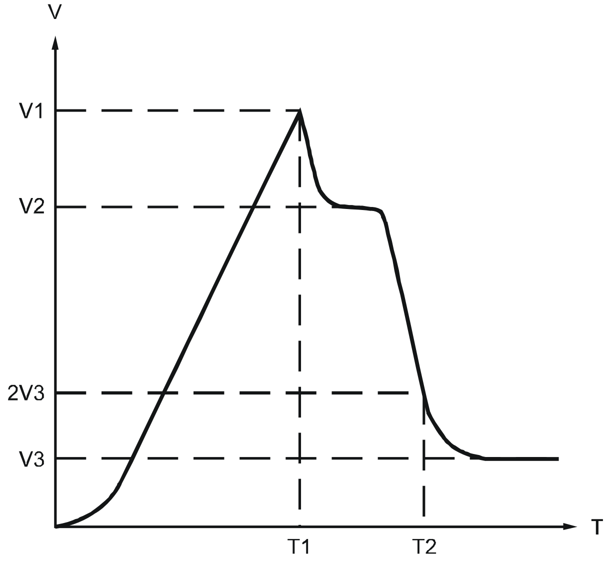

T2-T1= transition time
V1 = breakdown (sparkover) voltage
V2 = glow voltage
V3 = arc voltage

NOTE—T2 is to be taken at a point when the voltage is equal to twice V3.

Figure 8—Breakdown waveform

4.14 Impulse transverse voltage test

A transverse voltage occurs across a balanced-to-ground conductor pair when symmetrical or unsymmetrical longitudinally impressed voltages break down the gaps of a surge-protective device, with either 2 two-electrodes gas-tubes or 1 three-electrode gas tube, that is connected to protect the insulation of the line pair to ground. The transverse voltage may also occur as the gaps return to their high-impedance state. It is the purpose of this test to determine the impulse transverse voltage.

The impulse generator for transient transverse voltage in Figure 9 shall be designed to generate a 10/1000 µs waveshape with a crest of 1500 V. The crest discharge current of the gas-tube device shall be a function of the applied crest voltage, the current limiting resistors as shown in Figure 9, and the inherent characteristics of the device under test.

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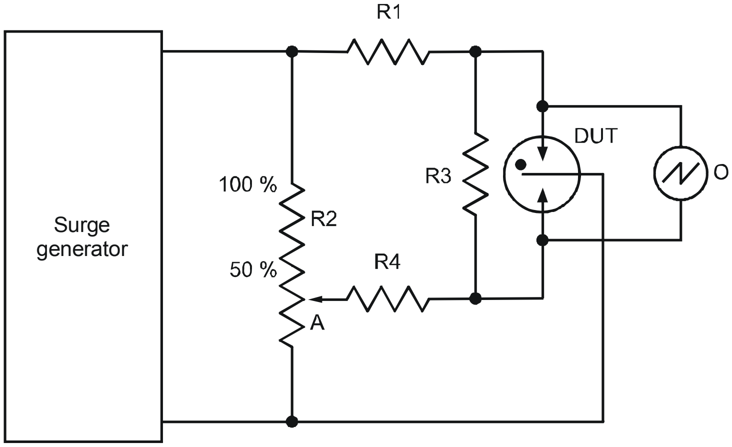


DUT = Device Under Test (gas-tube device)
O = oscilloscope or equivalent for observing transient transverse voltage
R1,R4 = current-limiting resistors
R2 = impulse wave-shaping resistor (≤20 % of R1)
R3 = termination resistor (600 Ω)

NOTE—The values in parenthesis are recommended in the absence of special requirements.

Figure 9—Circuit for impulse transverse voltage test

Table 3—Test plan for impulse transverse voltage test (Figure 9)

Test	R1, R4 Ω	A % of R2
1A	50	100
1B*	50	50
2A	800	100
2B	800	50
*Optional test		

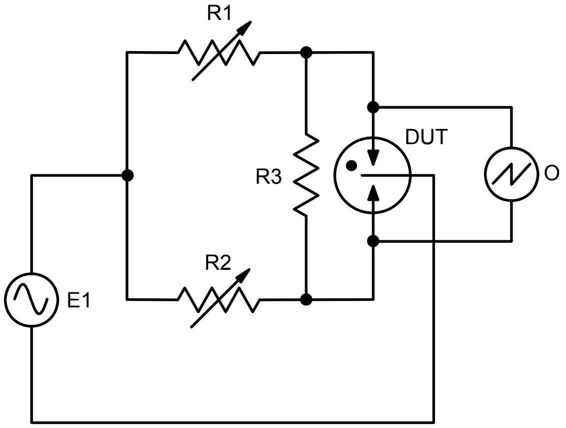
The test plan of Table 3 shall be performed. At each step, the transverse voltage shall be measured such that the transverse pulse shape can be established with respect to voltage amplitude and time duration. The area under the volt-time curve of the pulse will represent volt-seconds relating to current or energy through the protected termination. Devices shall be tested in both polarities to determine the effect of polarity on impulse transverse voltage. For devices with backup air gaps, see 4.17.

NOTE—The characteristics of the specific system or circuit in which the device is applied may affect this electrical characteristic.

4.15 AC transverse voltage test

An ac transverse voltage test shall be made from an ac source, timer-controlled to limit discharge current to 0.2 s, as shown in Figure 10. Current limiting resistors shall allow a peak current of 1.5 to 4 times the glow-to-arc transition current through each gap. The source shall have a peak voltage value of 1.5 to 4 times the dc breakdown voltage of the device. The maximum peak transverse voltage and the maximum volt-time area for any half cycle shall be recorded.

The characteristics of the specific system or circuit in which the device is applied may affect this electrical characteristic of the device.



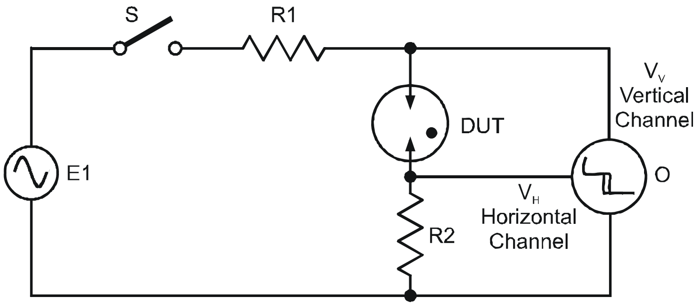
DUT = Device Under Test (gas-tube device)
E1 = 50 Hz or 60 Hz source
O = oscilloscope or equivalent for observing transverse voltage
R1,R2 = current-limiting resistors
R3 = termination resistor (600 Ω)

NOTE—The value in parenthesis are recommended in the absence of special requirements.

Figure 10—Circuit for ac transverse voltage test

4.16 Voltage-current characteristic test

A voltage-current characteristic shall be derived illustrating nominal values of breakdown, glow voltage, and the glow-to-arc transition current in both polarities of the device. The circuit in Figure 11 shall be used for this test, limiting current to the lowest value necessary to define the glow-to-arc transition. The source shall provide a single cycle of 50 Hz or 60 Hz voltage, with a peak value at least 1.5 times the dc breakdown voltage.



DUT = Device Under Test (gas-tube device)
E1 = 50 Hz or 60 Hz source
O = dual channel oscilloscope or equivalent
R1 = load-limiting resistor
R2 = current shunt resistor
S = switch
V_V = vertical signal
V_H = horizontal signal

Figure 11—Circuit for voltage-current characteristic test

4.17 Backup air gap devices

When performing the tests of 4.6, 4.7, 4.8, 4.10, 4.11, 4.12, 4.13 and 4.14 on devices equipped with backup air gaps, the maximum voltage rate-of-rise of the impulse or surge generator shall be specified.

NOTE—Depending on the design and gap spacing of the backup air gap, it is possible to fire the backup air gap before the gas-tube fires, which could lead to premature failure of the device that is not related to the gas-tube surge-protective device component.

When devices are not equipped with backup air gaps, optional test programs exist to determine the integrity of the gas-tube sealing process. If the gas tube does not vent its gas to the atmosphere during the test program, the need for a secondary means of protection (backup air gap) would be eliminated. The gas-tube seal test program can be found in the standards UL497 [B2] or Telcordia GR 1361 [B3].

4.18 Failure mode

In the absence of special requirements, the following criteria are suggested:

4.18.1 Short-circuit failure mode

In this mode, the device has become permanently short-circuited.

4.18.2 Low breakdown voltage failure mode

In this mode, a device has a dc breakdown voltage of less than a specified value.

4.18.3 High breakdown voltage failure mode

In this mode, a device has a dc or impulse breakdown voltage of greater than a specified value.

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4.18.4 Low insulation resistance failure mode

In this mode, a device has an insulation resistance of less than a specified value.

NOTE—In the absence of other requirements, it is recommended that a value of 1 MΩ be used.

4.18.5 DC holdover fault mode

In this mode, a device has a time for follow-current turnoff in excess of the specified maximum value. When applied in an impulse life test, dc holdover need not be checked after every impulse. It shall be sufficient to measure this characteristic at the completion of the maximum required number of impulses, and then only for those devices that survived to that point.

4.19 Fail-safe operation

The use of the term fail-safe to describe a failure mode of an gas-tube device is discouraged for the following reason. Failure of a device can occur in any of the modes previously described. Some users may consider that the short-circuit mode is the most desirable failure mode. However, system objectives of other users can require that a particular device should fail in a high breakdown failure mode in order to achieve the desired performance of the system. Thus, failure in the short mode, while considered fail-safe by many users, may in fact be opposite the desired (safe) mode of other users.

Therefore, the recommended practice is to describe the failure by one of the failure modes defined in 4.18.1 through 4.18.5.

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Annex A

(informative)

Bibliography

[B1] IEEE 100, *The Authoritative Dictionary of IEEE Standard Terms*, Seventh Edition, New York, The Institute of Electrical and Electronics Engineers, Inc.

[B2] UL497, *Protectors for Paired Conductor Communications Circuits*, Fifth edition, July 25-1995, clause 41a.

[B3] Telcordia GR 1361, *Generic Requirements for Gas Tube Protectors*, Issue 2, Sept. 1998.

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