

IEEE Standard Test Methods for Surge Protectors Used in Low- Voltage Data, Communications, and Signaling Circuits

Sponsor

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of the
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Abstract: Methods for testing and measuring the characteristics of surge protectors used in low-voltage data, communications, and signaling circuits with voltages less than or equal to 1000 V rms or 1200 V dc are established. The surge protectors are designed to limit voltage surges, current surges, or both. The surge protectors covered are multiple-component series or parallel combinations of linear or nonlinear elements. Tests are included for characterizing standby performance, surge-limiting capabilities, and surge lifetime. Packaged single gas-tube, air-gap, varistor, or avalanche junction surge-protective devices are not covered, nor are test methods for low-voltage power circuit applications.

Keywords: communications circuits, current limiters, data circuits, electrical protection, signaling circuits, surge protectors, surge-protective devices, voltage limiters

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Introduction

(This introduction is not a part of IEEE Std C62.36-2000, IEEE Standard Test Methods for Surge Protectors Used in Low-Voltage Data, Communications, and Signaling Circuits.)

This standard was developed to establish methods for testing characteristics and for identifying criteria that determine the end-of-life for surge protectors used in low-voltage data, communications, and signaling circuits. The surge protectors covered are multiple-component series or parallel combinations of linear or non-linear elements packaged for the purpose of limiting surge voltages, currents, or both.

Since these test methods and criteria apply to a range of surge protectors used in various environmental conditions, and include various combinations of elements, some tests are not appropriate for some surge protectors. Manufacturers and users may determine which tests apply to a surge protector intended for a specific application. These standard test methods should improve the consistency of information on data sheets for the covered surge protectors.

The need for this standard arose because of the following industry trends:

- a) The development and proliferation of surge protection devices that use solid-state components to limit current or voltage
- b) The manufacture and use of multiple-component surge protectors
- c) The increasing use of sensitive electronic circuits that require protection if exposed to surges from the environment

This edition of the standard includes test methods for surge protectors intended for use on coaxial and twinaxial circuits. The tests for insertion loss and return loss are modified to use network analyzers in high-frequency applications. A test has been added to measure the degree of coupling between ports of a multiport surge protector, and the ability of a surge protector to satisfy a pulse mask test. The tests for analog and digital insertion loss have been combined into a single insertion loss test. The test levels and configurations for several of the impulse tests have been updated. Information has been included on general methods for test measurements.

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IEEE Standard Test Methods for Surge Protectors Used in Low-Voltage Data, Communications, and Signaling Circuits

1. Scope

This standard applies to surge protectors for application on multiconductor balanced or unbalanced data, communications, and signaling circuits with voltages equal to or less than 1000 V rms, or 1200 V dc. These surge protectors are designed to limit voltage surges, current surges, or both.

This standard describes the methods of testing and criteria for determining the end of life of electrical surge protectors used in low-voltage data, communications, and signaling circuits. The surge protectors covered are multiple-component series or parallel combinations of linear or nonlinear elements, packaged for the purpose of limiting voltage, current, or both.

This standard is not intended to cover packaged single gas tube, air gap, varistor, or avalanche junction surge-protective devices, which are included in IEEE Std C62.31-1987,¹ IEEE Std C62.32-1981, IEEE Std C62.33-1982, and IEEE Std C62.35-1987, respectively. Specifically excluded from this standard are test methods for low-voltage power circuit applications. For protection of wire-line communication facilities under the specialized conditions found at power stations, consult IEEE Std 487-1992.

The tests in this standard are intended as design tests, as defined in the IEEE Dictionary [B1]², and provide a means of comparison among various multiple-component surge protectors.

The test criteria and definitions of this standard provide a common engineering language beneficial to users and manufacturers of multiple-component surge protectors.

¹Information on references can be found in Clause 2.

²The numbers in brackets correspond to those in the bibliography in Annex D.

CAUTION

Because of the voltage and energy levels employed in the majority of tests described herein, all tests should be considered hazardous. Appropriate caution should be taken in their performance.

2. References

This standard shall be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the revision shall apply.

IEEE Std 455-1985 (Reaff 1992), IEEE Standard Test Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band.³

IEEE Std 487-1992, IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations.

IEEE Std 743-1995, IEEE Standard Equipment Requirements and Measurement Techniques for Analog Transmission Parameters for Telecommunications.

IEEE Std C62.1-1989 (Reaff 1994), IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits.

IEEE Std C62.31-1987 (Reaff 1998), IEEE Standard Test Specifications for Gas-Tube Surge-Protective Devices.

IEEE Std C62.32-1981 (Reaff 1997), IEEE Standard Test Specifications for Low-Voltage Air Gap Surge-Protective Devices.

IEEE Std C62.33-1982 (Reaff 1994), IEEE Standard Test Specifications for Varistor Surge-Protective Devices.

IEEE Std C62.35-1987 (Reaff 2000), IEEE Standard Test Specifications for Avalanche Junction Semiconductor Surge Protective Devices.

IEEE Std C62.41-1991 (Reaff 1995), IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

IEEE Std C62.45-1992 (Reaff 1997), IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits.

ITU-T Recommendation G.703 (1998), Physical/electrical characteristics of hierarchical digital interfaces.⁴

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁴ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>).

3. Definitions

This clause contains only those definitions of terms relating to surge protectors, occurring within this standard, that are not given in the IEEE Dictionary [B1].

3.1 blocking voltage: The maximum voltage that can be applied to current-limiting pairs of terminals of a surge protector containing one or more current-protective devices without degradation of the surge protector.

3.2 multiport surge protector: A surge protector that provides surge protective function to two or more circuits, such as, but not limited to, paired conductors, coaxial cables, or mains, whereby all conductors connected to the protected circuits are routed through a common enclosure having a shared common terminal.

3.3 protector: *See: surge protector.*

3.4 surge protector: An assembly of protective devices consisting of one or more series, parallel, or any combination of elements used to limit surge voltages, currents, or both to a specified level. *Syn: protector.*

3.5 transition current: The current required at a given temperature and duration to cause a current-protective device to change state.

4. Service conditions

4.1 Normal service conditions

In the absence of special requirements, the following items should be specified as appropriate.

4.1.1 Environmental conditions

- a) Operating and storage temperature ranges
- b) Humidity
- c) Mechanical shock and vibration
- d) Atmospheric pressure range

4.1.2 Physical properties

- a) Solvent resistance
- b) Solderability
- c) Flammability
- d) Package rupture during overload
- e) Electrical connection to metallic case

4.1.3 System conditions

- a) Nominal system frequencies
- b) Maximum continuous system voltage
- c) Peak impulse currents
- d) Transient repetition rate

4.1.4 Surge rating of the surge protector under system conditions

- a) Rated average power dissipation
- b) Peak pulse power or current temperature derating
- c) Lifetime rated pulse currents

4.2 Unusual service conditions

The following service conditions may require special consideration in the design or application of surge protectors and should be called to the attention of the manufacturer.

4.2.1 Environmental conditions

- a) Ambient temperature exceeding the normal service conditions
- b) Exposure to
 - 1) Damaging fumes or vapors
 - 2) Excessive dirt or current-conducting deposits, excessive humidity, moisture, dripping water, steam or salt spray, explosive atmospheres, abnormal vibrations, and shocks
- c) Unusual transportation or storage conditions
- d) Flammability rating

4.2.2 Physical conditions

Limitation on weight or space, including clearance to nearby conducting objects.

4.2.3 System conditions

- a) System voltages, currents, repetition rates, or frequency operating conditions whereby the ratings of the devices are exceeded (see Clause 9)
- b) System impulse currents exceeding the rating of the device (see Clause 9)
- c) Exposure to direct lightning strike (see Clause 9)
- d) Electromagnetic field effects (see Clause 9)
- e) Unusual ground potential situations (see Clause 9)
- f) Any other unusual conditions known to the user

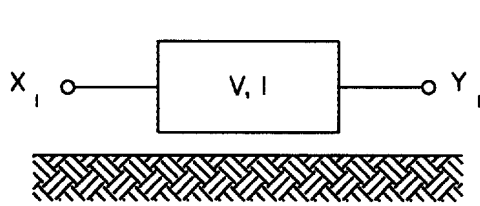
4.3 Radiation

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

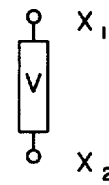
5. Basic configurations

This clause illustrates, by functional block diagrams, the surge protectors described by this standard. A protector assembly may be composed of any number of the protectors in Figure 1.

TWO-TERMINAL DEVICES

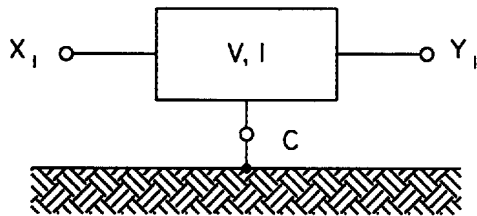


CONFIGURATION 2A

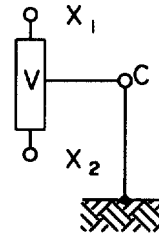


CONFIGURATION 2B

THREE-TERMINAL DEVICES

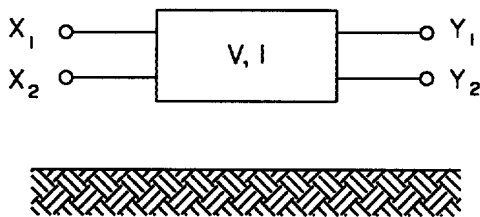


CONFIGURATION 3A



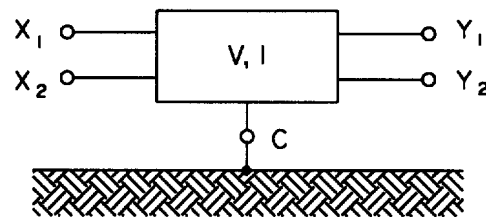
CONFIGURATION 3B

FOUR-TERMINAL DEVICE



CONFIGURATION 4

FIVE-TERMINAL DEVICE



CONFIGURATION 5

C = common terminal
I = current-limiting function
V = voltage-limiting function
X₁, X₂, Y₁, Y₂ = signal terminals

NOTES

1—The V,I designation in Figure 1 indicates that a surge protector may have a voltage-limiting function, a current-limiting function, or both.

2—Surge protectors intended for coaxial cable circuits shall be tested, as described in Clause 7 and Clause 8, using Configuration 3A. Outer conductors of the transmission lines are connected to the common terminal of the surge protector during the tests. (See examples of surge protectors on coaxial lines in Figure A.2.)

3—Surge protectors intended for twinaxial cable circuits shall be tested, as described in Clause 7 and Clause 8, using Configuration 5. Outer conductors of the transmission lines are connected to the common terminal of the surge protector during the tests. (See examples of surge protectors on twinaxial lines in Figure A.3.)

Figure 1—Basic configurations

6. Standard design test procedure

6.1 Standard design test criteria

The design tests described in Clause 7 and Clause 8 provide standardized methods for making single observations of a specified characteristic of a surge protector. These properties may vary from device to device, making it necessary to provide statistical descriptions of the property in order to compare products.

6.2 Statistical procedures

The following procedure shall be used to describe any characteristic 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 IEEE Dictionary [B1]. A sufficient number of devices shall be tested and the characteristic or rating in question measured as described in the applicable design test until the parameters of the underlying statistical distribution are determined within specified confidence limits. Values relating to the product sample, such as, but not limited to, mean, median, maximum, minimum, and standard deviation, may then be stated.

6.3 Test conditions

The tests in Clause 7 and Clause 8 shall be performed on the surge protector as required by the application. Unless otherwise specified, ambient test conditions shall be as follows:

Temperature:	25 °C ± 5 °C
Relative humidity:	less than 85%
Atmospheric pressure:	60–78 cm of Hg

For temperatures other than 25 °C, the surge protector, mounted as intended to be used, shall be maintained at the specified test temperature but with the air flow controlled to provide a free convection heat transfer, unless otherwise specified. The protector temperature shall be allowed to stabilize before tests are performed.

6.4 Test measurements

General guidance on test measurement techniques that has been useful in measuring the characteristics of surge protectors is contained in Annex C.

7. Nonsurge performance tests

The following nonsurge voltage and current tests are intended to establish that, in its quiescent state, the surge protector does not disturb operation of the protected circuit.

7.1 Rated voltage test

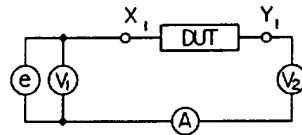
The purpose of this test is to verify that the surge protector can be used continuously at a specified maximum voltage, frequency, and temperature without undesirable signal distortion, undesirable power loss, or failure.

7.1.1

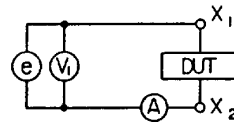
The surge protector shall be tested under one or any combination of the following conditions, using test circuits functionally equivalent to those shown in Figure 2:

- At specified voltage e and frequency. The voltage shall be stated as rms, ac peak, or dc.
- At specified maximum and minimum ambient temperatures. The protector with voltage applied shall be allowed to stabilize for 24 h at the ambient temperatures before the measurements are made.
- Unless otherwise specified, no load shall be connected to the protector terminals.

TWO-TERMINAL DEVICES

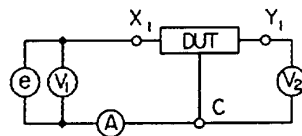


CONFIGURATION 2A

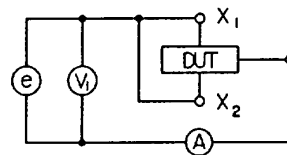


CONFIGURATION 2B

THREE-TERMINAL DEVICES



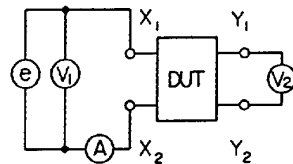
CONFIGURATION 3A



CONFIGURATION 3B

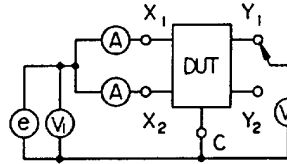
NOTE: THREE-TERMINAL DEVICES OF CONFIGURATION 3B SHOULD ALSO BE TESTED IN CONFIGURATION 2B, WITH TERMINAL C LEFT FLOATING.

FOUR-TERMINAL DEVICE



CONFIGURATION 4

FIVE-TERMINAL DEVICE



CONFIGURATION 5

NOTE: FIVE-TERMINAL DEVICES SHOULD ALSO BE TESTED IN CONFIGURATION 4, WITH TERMINAL C LEFT FLOATING.

A	=	ammeter, for reading current A
C	=	common terminal
DUT	=	device under test
e	=	source voltage, for providing voltage level e
V_1, V_2	=	suitable voltage-measuring instruments, e.g., oscilloscopes, for measuring voltages V_1 and V_2
X_1, X_2, Y_1, Y_2	=	signal terminals

**Figure 2—Test circuits for the rated voltage test
(configurations refer to Figure 1)**

7.1.2

Observe the amplitudes and waveshapes of voltage V_1 and voltage V_2 . Measure the current by means of a suitable ammeter, A , or by a current shunt and an oscilloscope. When making voltage measurements, the ammeters shall be removed from the circuit. When making current measurements, the voltage-measuring instruments shall be removed from the circuit.

7.1.3

After the temperature stabilization period, the surge protector shall not exhibit specified failure modes (see Clause 9) and shall meet the following criteria:

- a) The protector shall not limit nor distort voltages V_1 or V_2 beyond a specified amount.
- b) The current, A , shall not exceed a specified value at the ambient temperature of the test. (This current may be referred to as leakage current.)

7.2 Rated current test

This test is conducted to verify that a surge protector does not degrade normal circuit functions while carrying the rated current.

7.2.1

The surge protector is to be tested under the following conditions, using the appropriate test circuit, as shown in Figure 3:

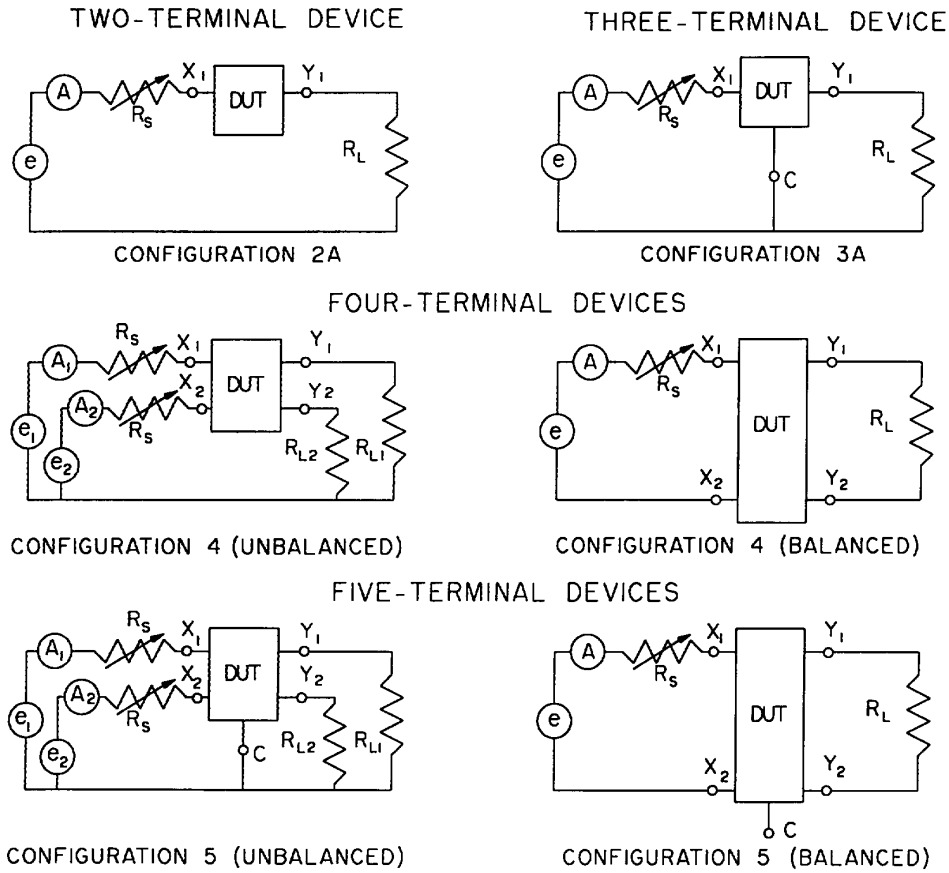
- a) At rated frequency, dc, or as specified.
- b) Maximum ambient temperature of the application, or as specified.
- c) A continuous current, I , specified by its dc, ac rms, or ac peak value (+5%, –0%), is to be adjusted by means of the source resistance, R_s , with the protector in the circuit.
- d) The test shall be conducted until temperature stabilization of the protector occurs.
- e) The voltages e , e_1 , and e_2 shall be the rated voltage(s). Normally $e_1 = e_2$, except where opposite polarity is an important requirement.
- f) R_L shall approximate the load resistance of the intended application.
- g) For ungrounded circuit applications, the circuits in Configuration 2A, Configuration 4 (balanced), and Configuration 4 (unbalanced) of Figure 3 shall be used.
- h) For multicircuit devices, as many circuits as are expected to be active at the same time shall be simultaneously exposed to the rated current.

7.2.2

At the conclusion of the test, the surge protector shall not experience a failure mode relevant to the application (see Clause 9). The voltage across R_L shall not have more than a specified increase in total harmonic distortion as compared to the value measured with the protector replaced by a short circuit. In the absence of specified requirements, the increase shall not exceed 1%.

7.3 DC series resistance test

This test is conducted to determine the dc series resistance between specified terminals of a surge protector.



A, A ₁ , A ₂	=	ammeters or oscilloscopes with current shunts, for reading current A
C	=	common terminal
DUT	=	device under test
e, e ₁ , e ₂	=	dc or sinewave sources with less than 1% total harmonic distortion, for providing voltage level e
R _L , R _{L1} , R _{L2} , R _S , R _{S1} , R _{S2}	=	noninductive resistors
X ₁ , X ₂ , Y ₁ , Y ₂	=	signal terminals

Figure 3—Test circuits for the rated current test

7.3.1

The resistance between specified terminals shall be determined. One pair of terminals shall be measured at a time; all terminals not involved in the measurement shall be left open-circuited. The test current and polarity shall be specified; the current shall be less than or equal to the rated current. The voltage across the tested terminals shall be measured.

The dc series resistance is the measured voltage divided by the test current.

7.4 Standby current and insulation resistance test

This test is conducted to determine the dc standby current and insulation resistance between specified terminals of a surge protector.

One pair of terminals shall be measured at a time; all terminals not involved in the measurement shall be left open-circuited. The test voltage, polarity, and temperature shall be specified; the voltage shall be less than or equal to the rated voltage. The current conducted by the tested terminals shall be measured. The current shall be measured after the voltage has been applied for at least 100 ms, unless it is known that the protector does not contain a gap-type device, in which case the current may be measured after 10 ms.

The measured current is the standby current (also known as the leakage current). The insulation resistance is the test voltage divided by the measured current.

NOTE—Insulation resistance to external surfaces of the surge protector may be measured by such methods as surrounding the external surface with a conducting material and considering that material as a test terminal.

7.5 Capacitance test

This test is conducted to determine the capacitance between specified terminals of a surge protector.

The capacitance between specified terminals shall be measured at a specified sinusoidal frequency and bias voltage. One pair of terminals shall be measured at a time; all terminals not involved in the test shall be connected to a ground plane in the measuring instrument. In the absence of specified requirements, a signal of 1 V or less at a frequency of 1 MHz and a bias of 0 V dc are suggested.

7.6 Inductance test

This test is conducted to determine the inductance between specified terminals of a surge protector.

The inductance between specified terminals shall be measured at a specified sinusoidal frequency and bias current. One pair of terminals shall be measured at a time; all terminals not involved in the measurement shall be left open-circuited. In the absence of specified requirements, a frequency of 1 MHz and a bias current of 0 A are suggested.

7.7 Insertion loss test

This test is conducted to determine the loss of transmitted power at a specified frequency, or frequency range, caused by the insertion of a surge protector into a communication circuit in which the impedances of the signal source, transmission line, and load are matched.

7.7.1 General considerations

The configuration of the surge protector depends, in part, on the type of communication equipment and transmission lines it is used to protect. This, in turn, determines the type of test equipment necessary to perform the insertion loss test. In general, there are analog or digital signals, unbalanced and balanced communication circuits, twisted wire pair or coaxial transmission lines, and wire terminals or coaxial connectors.

The surge protector shall be tested at the specified ambient temperature (see 6.3).

If a surge protector has more than two ports, and the test equipment does not supply terminating provisions for the additional ports, then the test shall be performed with the untested ports terminated with the characteristic impedance of the circuit.

If specified, a bias voltage or current (not shown in Figure 4) shall be applied to the surge protector.

7.7.2 Measurement at frequencies below 1 MHz

For measurement of insertion loss for surge protectors used in low-frequency circuits (below 1 MHz), where the matched impedances of the source, transmission line, and load are not critical, a signal generator (analog or digital) and an oscilloscope may be used.

Set up the test circuit as shown in part (a) of Figure 4. Adjust the voltage level, V_0 , and the frequency of the signal source as specified. Insert the surge protector between the signal source and the load. Measure the voltage, V_2 , as shown in part (b) of Figure 4.

The insertion loss (in decibels) is determined by Equation (1).

$$\text{Insertion loss} = 20 \log (V_2/V_0) \quad (1)$$

7.7.3 Measurement at frequencies above 1 MHz

There is a wide choice of test equipment available to perform insertion loss tests. An example is a spectrum analyzer with a tracking generator. The test equipment chosen shall be suitable for the same type of communication system (i.e., analog or digital signals, balanced or unbalanced, twisted pair wire connections or coaxial connectors), and have the same characteristic impedance, as the circuit for which the surge protector is designed.

The test equipment is calibrated and operated in accordance with the manufacturer's instructions and, usually, the cables and connectors needed to insert the surge protector are connected, and their losses are nulled from the subsequent measurement of the insertion loss of the surge protector. The surge protector is inserted, and the instrument displays the insertion loss in decibels caused by the surge protector.

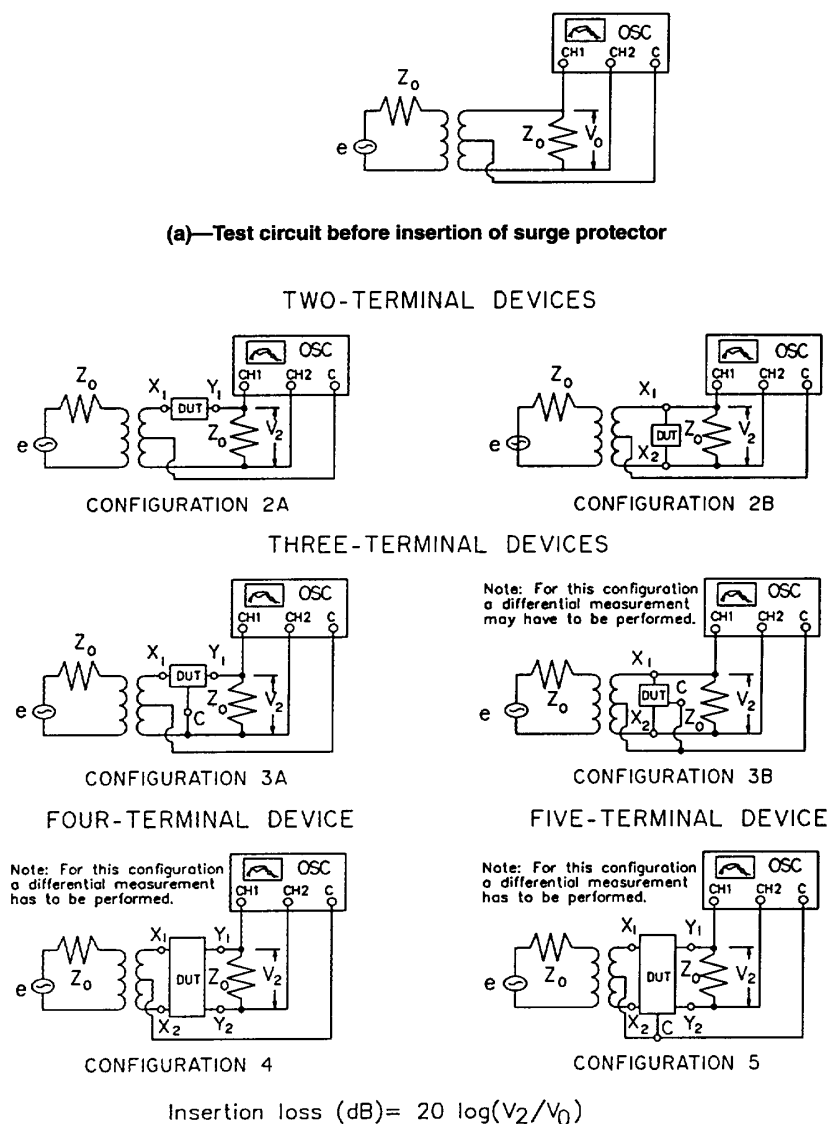
If the available test equipment does not provide the proper terminations required by the surge protector, then adapters, such as connectors or transformers, shall be used. It is important that these adapters have the same characteristic impedance as the rest of the circuit, and that the losses caused by the adapters are excluded (nulled) from the insertion loss measurement of the surge protector.

7.8 Phase shift test

This test is conducted to determine the phase shift of a sinusoidal voltage signal of specified frequency, or frequency range, caused by the insertion of a surge protector into the signal path.

Set up the test circuit as shown in Figure 5. Adjust the voltage level V_1 and the frequency as specified. The surge protector shall be at the specified ambient temperature (see 6.3). Measure the time delay between the two voltage waveshapes as they pass through the 0 V reference line.

NOTE—A specified bias voltage or current (not shown in Figure 5) may be applied to the surge protector.



(b)—Test circuits after insertion of surge protector

C = common terminal
CH₁, CH₂ = oscilloscope channels 1 and 2
DP = differential measuring probe
DUT = device under test
e = signal source, for providing voltage level e
OSC = oscilloscope
V₁ = input voltage
V₂ = output voltage
X₁, X₂, Y₁, Y₂ = signal terminals
Z₀ = terminating and source resistor matching the characteristic impedance of the system

NOTES

- 1—Configuration 5, as shown in Figure 1, can be tested in the same manner as Configuration 4, but with the common terminal (C) connected to the common terminal of the transformer.
- 2—This test does not apply to Configurations 2B and 3B, since they do not cause voltage phase shifts.

Figure 4—Test circuits for the insertion loss test