

American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment

Accredited Standards Committee on Electromagnetic Compatibility, C63

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Secretariat

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Abstract: Based upon ESD events on electronic equipment in actual-use environments, a process to establish ESD test criteria is provided. Test procedures for highly repeatable ESD immunity evaluation of tabletop and floor-standing equipment are described. Simulator characteristics for hand/metal and furniture ESD testing are specified both for air and contact discharge methods. Statistical criteria is given to determine the number of test trials required, based on the confidence factor desired and various pass/fail categories. This ANSI ESD guide has been harmonized with other international ESD standards except where other standards have technical approaches that would reduce equipment quality or result in degraded product operation.

Keywords: air discharge, contact discharge, coupling plane, direct discharge, electrostatic discharge (ESD), ESD event, ESD simulator, ESD test criteria, ESD waveform characterization, furniture ESD, hand/metal ESD, human/touch ESD, indirect discharge

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Introduction

(This introduction is not a part of ANSI C63.16-1993, American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment.)

This document is intended to serve as a guide when performing electrostatic discharge (ESD) testing. It incorporates the latest research in ESD waveform characterization and strives to ensure product quality through proper operation in actual equipment installations. The suggestions provided herein should not be construed as mandatory nor should they be blindly applied to all types of electronic equipment. Performance or acceptance test levels are not given in this document. The specification of performance or acceptance levels for any particular type of electronic equipment properly remains the prerogative of manufacturers and users of the particular equipment.

Two models, the human body with metal object model (hand/metal) and the furniture discharge model are used for each testing methodology. Indirect contact testing to coupling planes is described for each testing methodology. Test descriptions for floor-standing and tabletop electronic equipment are given. Statistical criteria is given to determine the number of test trials based on the confidence factor desired and various pass/fail categories.

Although it was the intent to harmonize this ANSI guide wherever possible with IEC 801-2 (1991), the technical differences between the two guides are such that a complete harmonization is impossible. This ANSI guide includes information and guidance not included in that document, such as: furniture ESD simulation, statistical determination of the number of ESD discharges per test point, confidence level solution, and, probably most importantly, test waveforms more closely depicting the ESD waveforms as they occur in equipment installations.

Because of the complexity of ESD, the variations in types of electronic equipment, and the many different actual use environments, it is a necessity for the reader to review and understand this guide in its entirety prior to commencing equipment testing.

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American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment

1. Scope

This guide describes methodologies for electrostatic discharge (ESD) testing of electronic equipment. The test methods and parameters described herein are chosen for standardization and repeatability of test results. This guide also recommends test criteria for evaluating equipment exposure and response to ESD. This guide does not set ESD test limits nor deal with equipment transient response to lightning, high-voltage breakdown, dielectric withstand, power line corona, or nuclear electromagnetic pulse.

2. Overview

2.1 General

An ESD event occurs when the local electric field between two bodies at different potentials exceeds the dielectric strength of air. When the ESD event occurs, the resulting current flow produces both magnetic and electric fields.

The nature of the ESD event has resulted in the following two testing philosophies:

- a) Air discharge test
- b) Contact discharge test

The goal in both cases is to determine the immunity of the equipment under test (EUT) to an ESD event.

The air discharge simulator attempts to reproduce the actual ESD occurrence by creating a spark in air. This approach may not produce repeatable waveforms [B6], [B23].¹ In the contact discharge simulator, the arc occurs inside the simulator under controlled conditions. This approach yields a repeatable waveform [B17]. The information in 7.1.1 and annex D will assist the user in determining the test method that is most suitable for the application.

Further information about actual ESD events may be found in annex E of this guide and in IEEE Std C62.47-1992².

¹The numbers in brackets correspond to those in the bibliography in clause 10.

²Information on references can be found in clause 3.

2.2 Comparison with other ESD standards

This guide is written with reference to existing and draft international ESD standards, especially IEC 801-2 (1991) and CISPR 24. It is a guide, not a standard. As a guide, it should not be considered to be in conflict with these standards; rather, this guide will enhance them, improving ESD testing of equipment and the quality of that equipment as a result of the additional information presented. [Comparisons between IEC 801-2 (1991) and this guide are given in annex F.]

This guide includes all of the main elements of the IEC 801-2 (1991) and CISPR 24 standards: the contact discharge method, the hand/metal source model, and the direct and indirect applications of ESD events to the EUT. This guide also includes information and material not found in these standards. This information is needed to complete the goals of ESD testing, primarily

- To ensure the quality of products and equipment through proper operation in actual-use environments (where ESD events occur)
- To have an ESD testing and evaluation procedure that is both realistic and workable, and that yields repeatable results

The key enhancements toward understanding ESD processes provided by this guide are as follows:

- a) A more complete treatment of the air discharge test method (including a more accurate specification and verification of the simulator's performance)
- b) Information comparing actual ESD events as they occur in nature to the parameters recommended in this guide
- c) Information comparing the parameters of this guide to those of IEC 801-2 (1991)
- d) Guidance on when to use the air discharge method and when to use the contact discharge method (including advantages and disadvantages of each method)
- e) A source model that simulates discharges from mobile office furnishings
- f) Statistical guidance for selecting test voltage levels, number of test trials, and evaluation of test results, instead of an arbitrary voltage limit and number of discharges

The statistical guidance will help the user of this guide locate product susceptibility windows, which is crucial for testing any equipment that has time-variant operational states, such as information technology equipment (ITE).

3. References

This guide shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

CISPR 24, Immunity of ITE—Part 2 (ESD), draft, Dec. 1989.³

IEC 801-2 (1991), Electromagnetic compatibility for industrial-process measurement and control equipment—Part 2: Electrostatic discharge requirements.⁴

IEEE Std C62.47-1992, IEEE Guide on Electrostatic Discharge (ESD)—Characterization for the ESD Environment.⁵

³CISPR publications are available from the International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse. CISPR documents are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁴IEC publications are available from IEC Sales Department, 3 rue de Varembe, Case Postale 131, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁵IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

4. Definitions

4.1 actual ESD events: Nonsimulated electrostatic discharges that occur in the intended environment of the electronic equipment.

4.2 air discharge method: A method of ESD testing in which the charged electrode of the ESD simulator approaches the EUT or coupling plane regardless of the conductivity of the ESD receptor. The discharge is actuated by a spark in air to the EUT or coupling plane.

4.3 charging current: The maximum continuous current at any charge voltage that may flow at the ESD simulator probe tip as measured to the return path of the simulator through a 1500 Ω resistor that is connected to the probe tip.

4.4 contact discharge method: A method of ESD testing in which the electrode of the ESD simulator is in firm contact with a conductive surface of the EUT or coupling plane prior to discharge. The discharge is actuated by a switching device (i.e., a relay) within the simulator.

4.5 controlled ESD environment: One in which an attempt is made to maintain charge levels on humans and objects below a certain level. Typical control measures include humidity controls, equipment earth grounding, use of antistatic materials, ionized air, and high-resistance discharge paths for humans.

4.6 coupling plane: A metal plate to which discharges are applied to simulate electrostatic discharge to objects adjacent (vertically or horizontally) to the EUT. *See also:* **HCP, VCP.**

4.7 direct ESD test: A test in which ESD is applied directly to the surface or structure of the EUT.

4.8 electrostatic discharge (ESD): The sudden transfer of charge between bodies of differing electrostatic potentials.

4.9 ESD event: The occurrence of a single ESD.

4.10 ESD receptor: The surface (or target) of the object at rest being subjected to the ESD event.

4.11 ESD response: The EUT reaction to ESD.

4.12 ESD simulator: A testing device used to simulate a human or furniture ESD event.

4.13 ESD test voltage: The amplitude (usually expressed in kV) of the initial electrostatic voltage that exists prior to discharge.

4.14 EUT: Equipment under test.

4.15 exerciser: A device used to operate the EUT.

4.16 failure: The inability of a product to meet its operating specification.

4.17 furniture ESD: An ESD in which the intruder is an inanimate object such as a cart or chair, with or without a human in physical contact with the object.

4.18 ground reference plane (GRP): A flat conductive surface whose potential is used as a common reference. Where applicable, the operating voltage of the EUT and the operator ground should also be referenced to the ground plane.

4.19 hand/metal ESD: An ESD from an intruding human hand that occurs from an intervening metal object such as a ring, tool, key, etc. *Also called:* hand/metal discharge.

4.20 HCP: Horizontal coupling plane. *See:* **coupling plane.**

4.21 holding time: The interval of time within which the decrease of the test voltage due to leakage, prior to the discharge, is not greater than 10% when measured with an instrument that has a dc resistance greater than $10^{16} \Omega$ and a capacitance less than 10 pF.

4.22 human/touch ESD: The ESD that occurs directly from a human fingertip, without the presence of any metallic structure in the ESD path.

4.23 indirect ESD test: A test in which ESD is applied to a coupling plane in the vicinity of the EUT.

4.24 intruder: A body that is in motion in an ESD event. The intruder is usually, but not necessarily, charged relative to its surroundings. It is always at a potential different from that of the receptor.

4.25 simulated ESD: An ESD that originates from an ESD simulator.

4.26 simulator approach speed: The rate at which an air discharge ESD simulator approaches the EUT or coupling plane.

4.27 table ESD test: An indirect test in which ESD is applied to the HCP.

4.28 uncontrolled ESD environment: One in which no attempt is made to maintain charge levels on humans and objects below a certain level.

4.29 undesirable response rate: The percentage of undesirable ESD responses exhibited by the EUT when subjected to a specific number of ESD events.

4.30 VCP: Vertical coupling plane. *See: coupling plane.*

5. Safety—ESD test operator cautions

The ESD simulator is a high-voltage instrument. Some are capable of producing voltage levels up to 25 kV. Although the energy level of a single discharge at this voltage is below that which is considered lethal for a normal, healthy adult, this energy level can give the user an unpleasant shock. Therefore, there is an inherent danger when performing ESD tests.

Operating and working around any high-voltage instrument or device requires a high degree of responsibility, care, and common sense. Normal high-voltage safety practices should be exercised when performing these tests. The ESD simulator manufacturer's safety practices should also be followed.

CAUTION

ESD testing may be hazardous to wearers of electronic life-support equipment. Personnel with pacemakers, heart problems, nervous disorders, and similar problems should not be allowed to operate the ESD simulator or be present during ESD testing.

6. Laboratory test conditions

The intent of ESD testing in the laboratory is to simulate both the level and type of ESD occurrences that are experienced by the product in the field in a manner that is representative of, but not necessarily identical to, actual ESD.

In order to minimize the effect of environmental parameters on the test results, ESD testing should be carried out under the conditions defined in this clause.

6.1 Climatic conditions

ESD testing should be performed under the following climatic conditions:

- a) Temperature: 15–27 °C (59–80 °F)
- b) Relative humidity (RH): < 50%
- c) Atmospheric pressure: 68–106 kPa

NOTES

1—Standard conditions are defined as sea level (101.3 kPa and 15 °C). Then 106 kPa is -383 m and 68 kPa is +3236 m altitude. International conversion for 1 kPa is 0.145 lbf/in² or 0.2953 inHg (typical reported atmospheric pressure measurement in the USA) and 10 mbar.

2—Tests can be performed outside the recommended climatic conditions. However, the results may be significantly affected with increased RH and variations in temperature.

The actual environmental conditions existing during the test should be recorded on the data sheet.

6.2 Air breakdown voltage test value

Air breakdown at a fixed distance between arcing electrodes is approximately proportional to atmospheric pressure and inversely proportional to absolute (K) temperature. Therefore, when testing EUTs for air breakdown (external or internal with either test method), the ESD test voltage level should be changed to reflect the test equipment specification and the environmental test conditions. Typically, air breakdown at sea level will be about 40% higher than at 3000 m. Failure to change the test voltage to account for pressure variation will create site-to-site immunity variations in the EUT air breakdown values.

6.3 Electromagnetic conditions

The ambient electromagnetic conditions should be such as not to influence the results of this test.

6.4 Test site description

6.4.1 General

Care should be exercised when selecting a site to perform ESD testing. The ESD impulse produces a broad spectral distribution of energy, and these emissions may cause damage or malfunction of unprotected equipment in the immediate area. Also, other equipment and activity in the immediate area can interfere with the ESD test. The ESD test site, therefore, should be located in an area that is of sufficient size to minimize interference.

Accordingly, it is recommended that a clear-area radius of at least 1 m be provided around the EUT and to any other metallic structure, including walls, so as not to impact the ESD test. Where possible, the EUT should be placed in a dedicated room with electrical isolation from unrelated equipment. Shielded rooms are not recommended for use as ESD test sites because of the possibility of creating standing waves that may affect the test results.

6.4.2 Size of ground reference plane (GRP)

A GRP of sufficient size to provide a continuous reference for the EUT, ESD simulator, and operator should be provided as part of the test site. The GRP on the floor is extended beyond the edges of the EUT at least 0.5 m for equipment up to 1 m in height, as well as for a tabletop test. To capture all edge effects for equipment over 1 m in height, the GRP should extend beyond the EUT at least 50% of the height of the EUT. An optional insulator, not to exceed 5 mm in thickness, may be placed over the GRP. The GRP should

be connected to the protective grounding system. Local safety regulations should always be met. See 7.4.1 for EUT ground connections.

NOTE—The GRP is not used during verification of the hand/metal ESD waveform for a lumped-element or hand-held simulator. A GRP should be used for a distributed capacitance simulator.

7. Test methods

The recommendations of this guide are based on the premise that products will be evaluated for ESD performance utilizing test simulation equipment that complies with the requirements delineated herein.

Discharge phenomena considered essential to product ESD performance are as follows:

- a) Discharges from human bodies through a metallic object (hand/metal)
- b) Discharges from metallic furniture

These ESD tests may be performed using air or contact ESD simulators. Human/touch ESD, though frequently encountered in the actual environment, is not delineated in this guide. See annex E.

7.1 Test method guidance

Tests may be performed utilizing air or contact ESD simulations for ESD events from humans holding small metal objects (hand/metal ESD) or from furniture. Subclauses 7.1.1 and 7.1.2 provide information relative to the use of these simulations.

7.1.1 Guidance—Air or contact ESD methods

The particular test method (air or contact ESD simulation) selected as appropriate for EUT evaluation should be determined by first establishing an intended result for the information that will be gained from the ESD test. The user of this guide should review the advantages and disadvantages of each method, as described in annex D, prior to selecting which test method to use. Items a) through c) briefly overview the processes involved with the two approaches.

- a) For EUTs with conductive surfaces, either the air or contact discharge method can be used for applying discharges.
- b) For EUTs with insulating surfaces, the air discharge method, by its nature, is predominantly used (see 7.5.4.4). The contact discharge test method may be used, but it will be an indirect test.
- c) When performing indirect ESD testing using coupling planes, either the air or contact test method may be used, but the contact discharge test method is preferred for reasons of repeatability.

7.1.2 Guidance—Hand/metal and furniture ESD simulations

ESD test evaluations of EUTs may be performed utilizing hand/metal or furniture simulations. The application of ESD from either simulation on the EUT is intended to be concentrated as follows:

- a) In physical areas likely to be touched by humans for the hand/metal condition
- b) In physical areas likely to be impacted by mobile furnishings

Either of these two simulations may additionally be applied to VCPs and HCPs for purposes of evaluating the EUT performance under the influence of indirect ESD.

These two simulation methods are not mutually exclusive, although in practice they could result in redundant testing in certain EUT areas. It is recommended, in 7.5.3, that furniture ESD simulations be applied to EUT areas that are contained below a boundary height of 1 m above the floor surface (for floor-

standing EUTs) and to the HCP below a tabletop EUT (i.e., to simulate ESD impacts from desk chairs to desks or tables). In addition, furniture ESD simulation could be applied to VCPs to evaluate the effect of indirect ESD from structures that are immediately adjacent to the EUT.

It should be noted that hand/metal ESD events can also be encountered in the same EUT areas (or indirect planes) as those evaluated for furniture ESD. When reviewing this overlap of EUT test areas and test simulations, it should be considered that the ESD impulse currents from the furniture events are more severe than those caused by the hand/metal events [B13], [B14], [B19], [B20], [B25], [B26]. This higher degree of severity caused by the furniture simulation may be realized by comparing table 3 to table 2 for air discharge (see 9.3) and table 5 to table 4 for contact discharge (see 9.4). For EUT areas (or indirect planes) where furniture ESD is viewed as applicable, further performance of ESD tests for hand/metal simulation in these areas becomes redundant.

In conclusion, there is not a single test that can address adequately the hand/metal and furniture ESD phenomena [B15]. A single test based on a furniture simulation may overestimate the equipment immunity since furniture ESD can only occur at certain points of the EUT. Some areas of the EUT are only touchable by humans. Conversely, a single test based on hand/metal discharge may overestimate the equipment immunity if the coupling is due to magnetic fields [B22].

7.2 Performance of the ESD simulator

The ESD simulators (like those described in annex A), capable of generating the waveforms in figures 1 through 4, should meet these specifications at any specified repetition rate used for compliance testing. Waveform characteristics are described in tables 2 through 5 (see 9.3 and 9.4). The dimensions of the discharge tips are given in figure 5 for both air and contact simulators.

The ESD simulator characteristics are as follows:

- a) Charging current (I_{ch}): ≤ 3.5 mA (dc) at any charge voltage
- b) Output voltage range: At least 1–6 kV for contact discharge; at least 2–15 kV for air discharge
- c) Accuracy of output voltage: $\pm 5\%$
- d) Polarity of the output voltage: see 7.3
- e) Holding time: at least 5 s

7.3 Application of the discharges

Discharges should be applied to all selected test points with the equipment operating normally. These test methods may also be applied to EUTs in a nonoperational state (e.g., not connected to an ac power source) to check for destructive responses. Hand/metal and furniture direct discharges, as well as indirect discharges, should be applied where appropriate as determined by the particular EUT and test points selected (see 7.5.3).

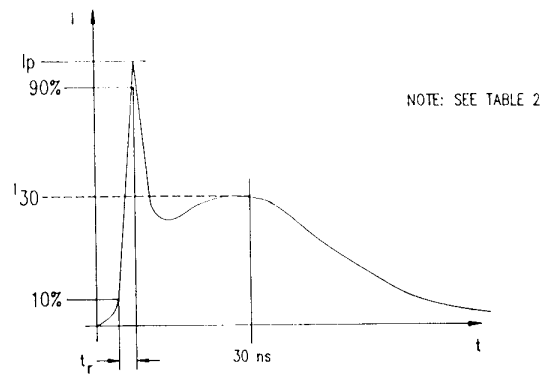
Product response may be affected by the polarity of the discharge. Both polarities of discharge should be used during exploratory testing to determine their effect on the EUT.

7.4 Test setup

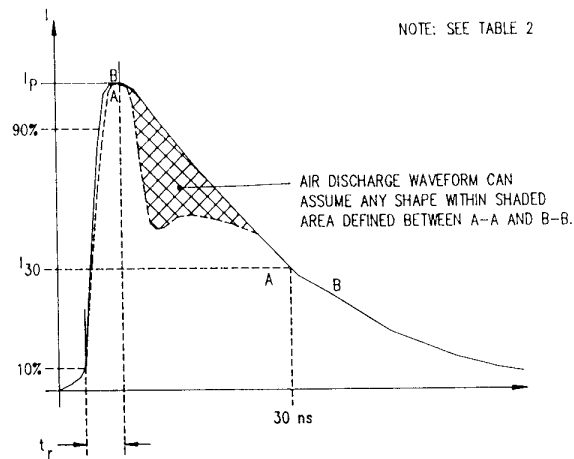
7.4.1 EUT configuration

The EUT should be configured in a manner representative of the equipment as typically used. A product that is marketed to be operated as a stand-alone device should be tested by itself. Conversely, a product designed and marketed to be operated as part of a multiunit system should be tested with peripherals, accessories, connecting cables, etc., attached and operating in a manner representative of actual use.

a) for discharge voltages less than 4 kV



b) for discharge voltages from 4–10 kV



c) for discharge voltages above 10 kV

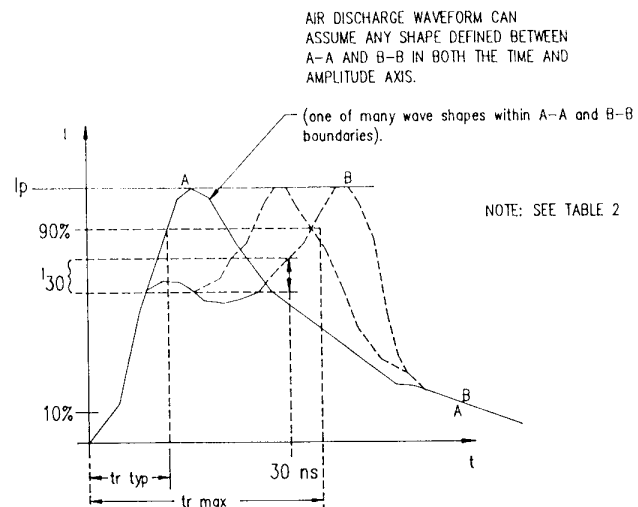


Figure 1—Simulator verification current waveform for hand/metal ESD (air)

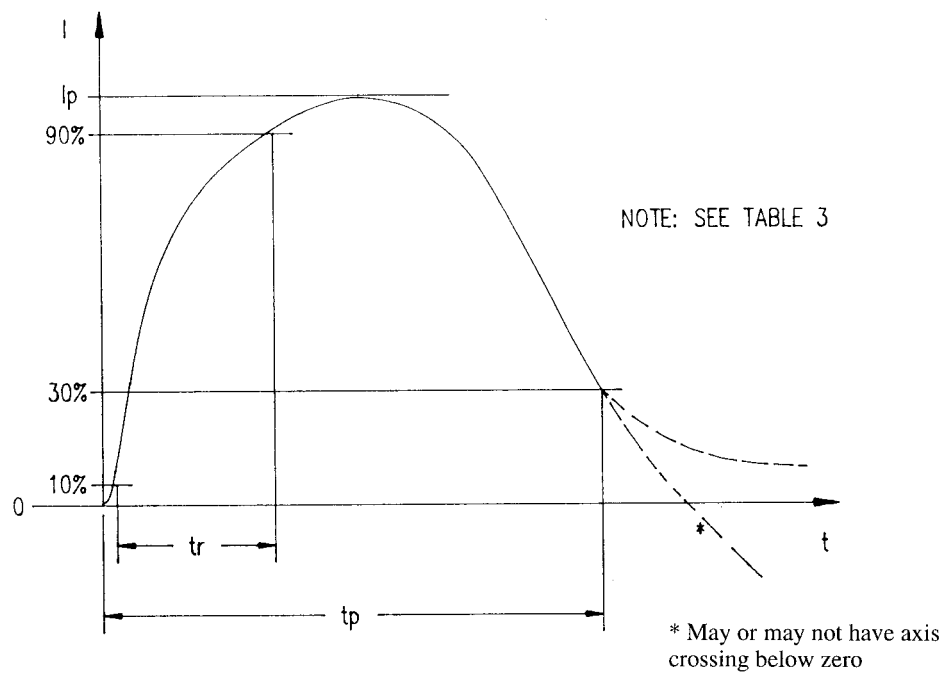


Figure 2—Simulator current waveform for furniture ESD (air)

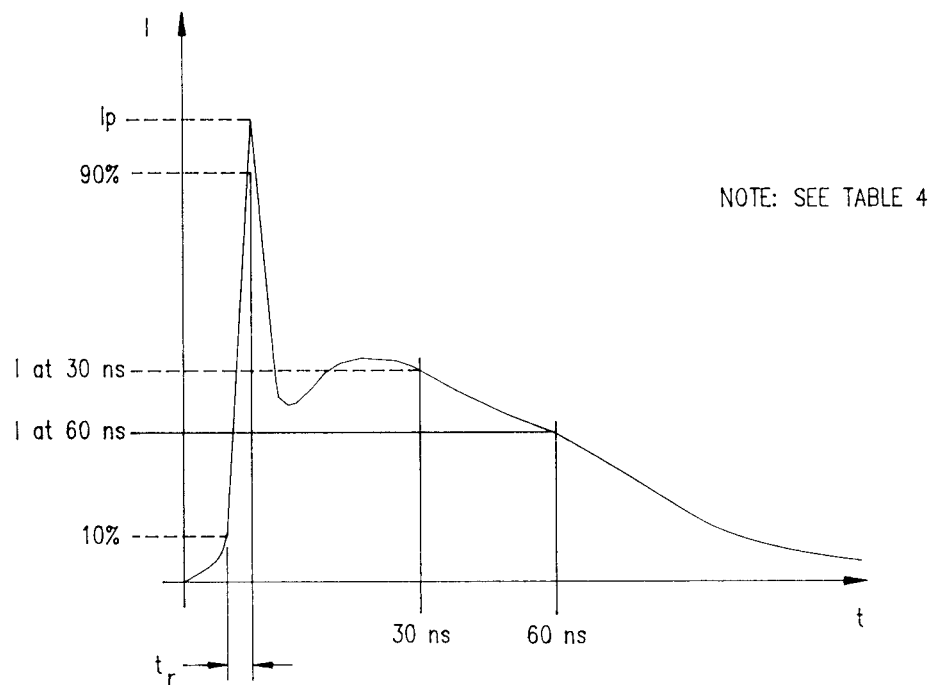


Figure 3—Simulator verification current waveform for hand/metal ESD (contact)

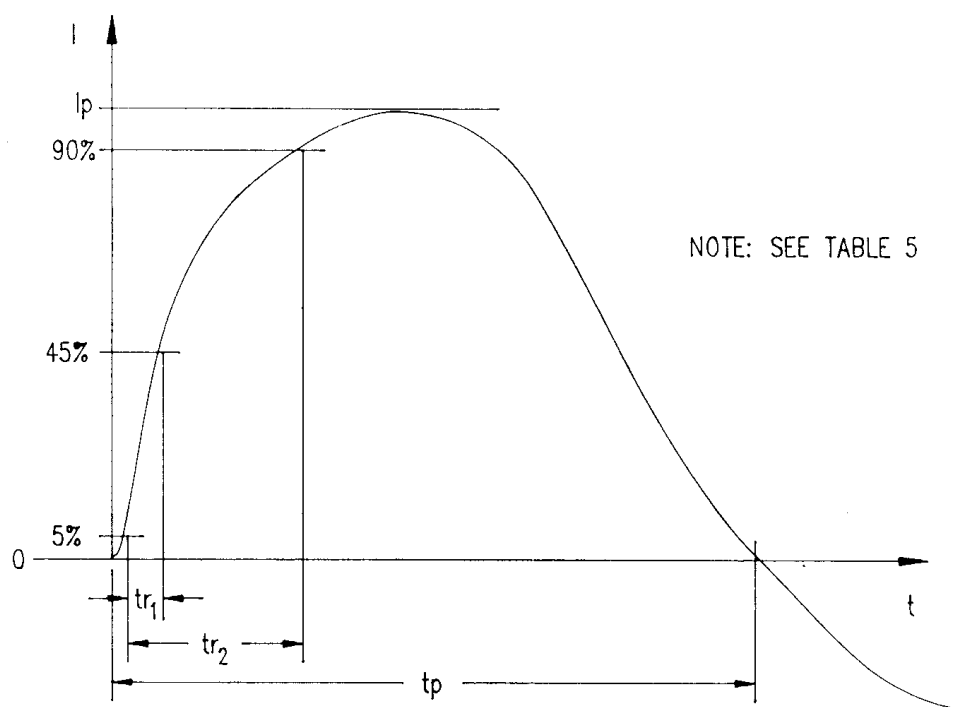


Figure 4—Simulator current waveform for furniture ESD (contact)

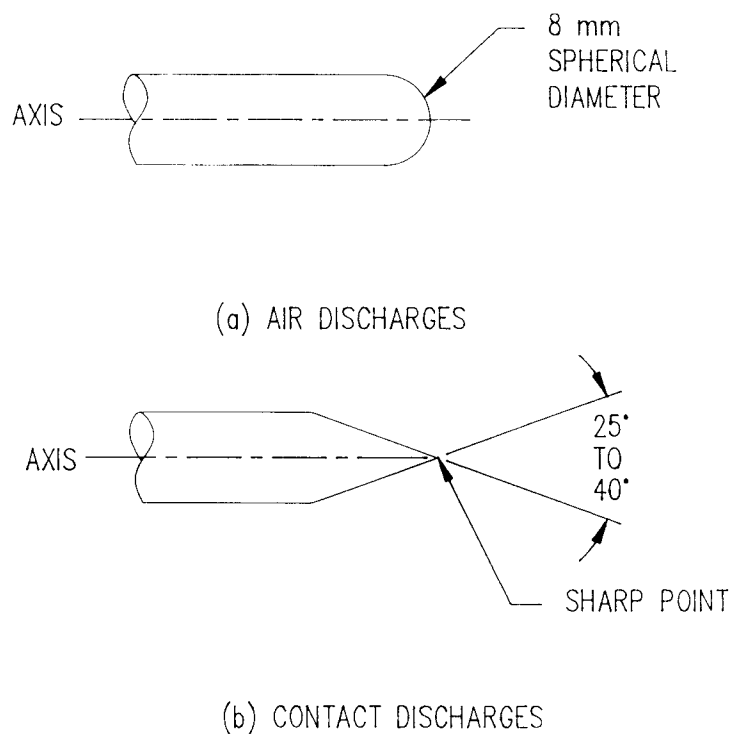


Figure 5—Discharge electrodes of the ESD simulator

Products may be tested when attached to an exerciser. In this case, the exerciser should be ESD hardened to facilitate a valid test. Because hardened exercisers are very difficult and expensive to obtain, a remotely located, unhardened exerciser may be used instead.

Ground connections other than those specified in the installation specifications should not be used during testing.

The EUT configuration, cables, modes of operation, and software used should be documented.

The disposition of the power and signal cables should be representative of typical installation practice. Less than maximum cable lengths are allowed. The cable lengths and layout used should be documented.

7.4.1.1 Tabletop equipment

The test setup uses a nonconductive table, 1.6 m by 0.8 m, and 0.8 m high, standing on the GRP. An HCP of the same size as the standard tabletop is placed on the tabletop.

The EUT and cables are isolated from the tabletop or coupling plane by an insulating support ≤ 0.5 mm in thickness, having a relative dielectric constant of 3 to 6. An example of the test setup for tabletop equipment is given in figure 6. See CISPR 24, IEC 801-2 (1991), and [B7].

If the EUT is too large to be located 0.1 m minimum from all sides of the HCP, an additional, identical HCP at the same height above the GRP is used, placed 0.3 m from the first, with the short sides adjacent. The HCPs are not bonded together other than via the resistive straps to the GRP in order to maximize the potential difference between them.

Any mounting feet associated with the EUT should remain in place.

7.4.1.2 Floor-standing equipment

The EUT is isolated from the GRP by an insulator not to exceed 5 mm in thickness. Any mounting feet associated with the EUT should remain in place. Refer to figure 7 for a typical setup.

7.4.2 Simulator return cable

The discharge return cable required in air and contact hand/metal simulators and certain types of air discharge furniture simulators (see annex A) is connected to the GRP as shown in figures 6 and 7. A cable longer than 2 m may be necessary to apply discharges to selected points. When testing such points while using a longer cable, the excess length over 2 m should be bundled noninductively off the GRP to avoid additional loops in the test circuit. For all discharge return cable lengths used, the simulator should meet the requirements of clause 9.

The connection of the simulator return cable to the GRP and all bonding should be of low impedance at high frequencies. The discharge return cable of the simulator (if required) should be positioned at least 0.2 m from the EUT while the discharge is being applied. This measure is needed to prevent radiation from this cable from affecting the test results. The end of the discharge return cable connected to the simulator may be closer to the EUT.

7.4.3 Distributed capacitance simulators

Crossed-vane or distributed capacitance simulators are normally used as furniture ESD simulators both for direct and indirect ESD testing. There should be a continuous GRP under the EUT and the distributed capacitance simulator for all ESD testing, direct or indirect, to ensure test stability.

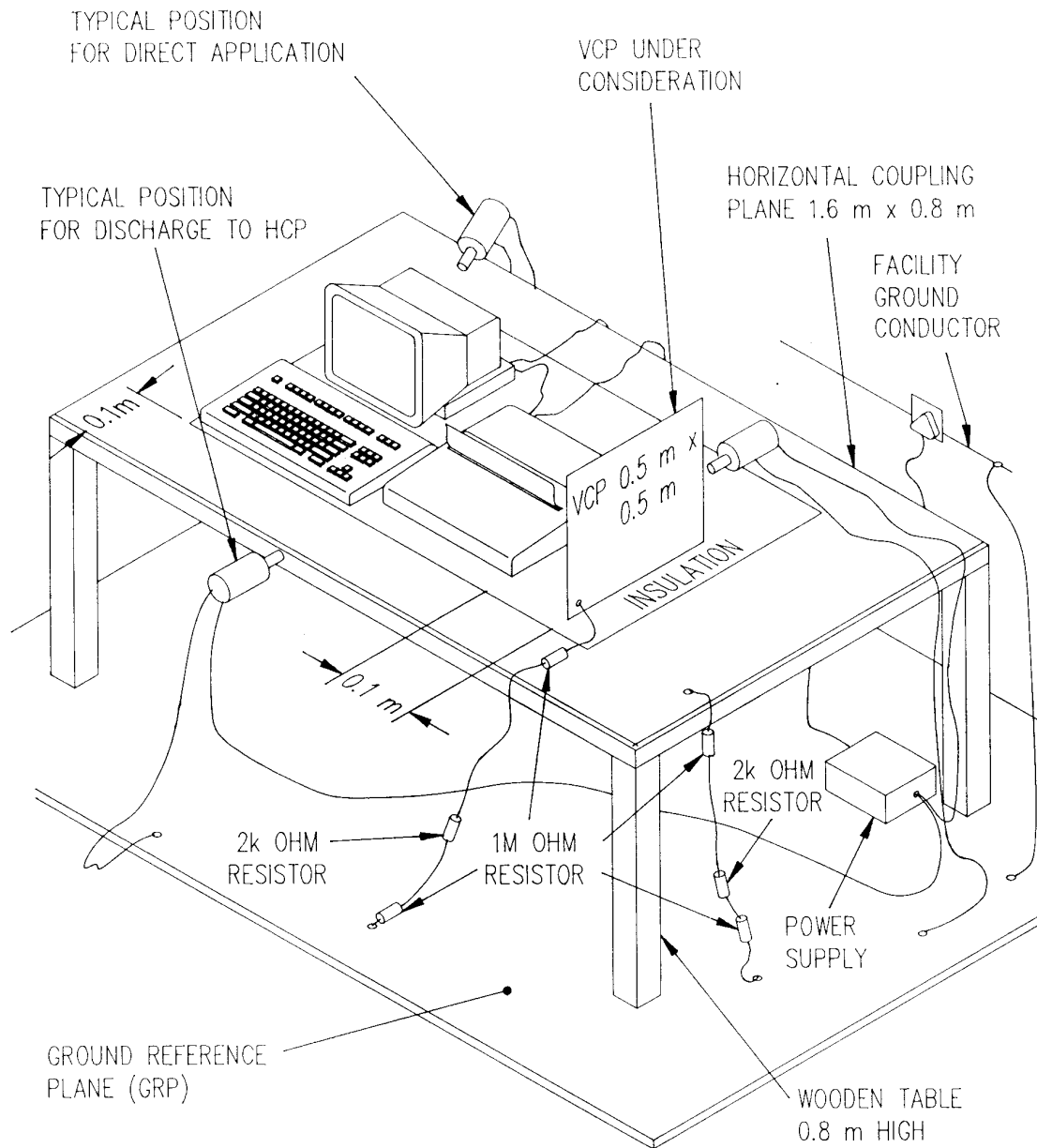


Figure 6—Test setup for tabletop equipment—Laboratory tests

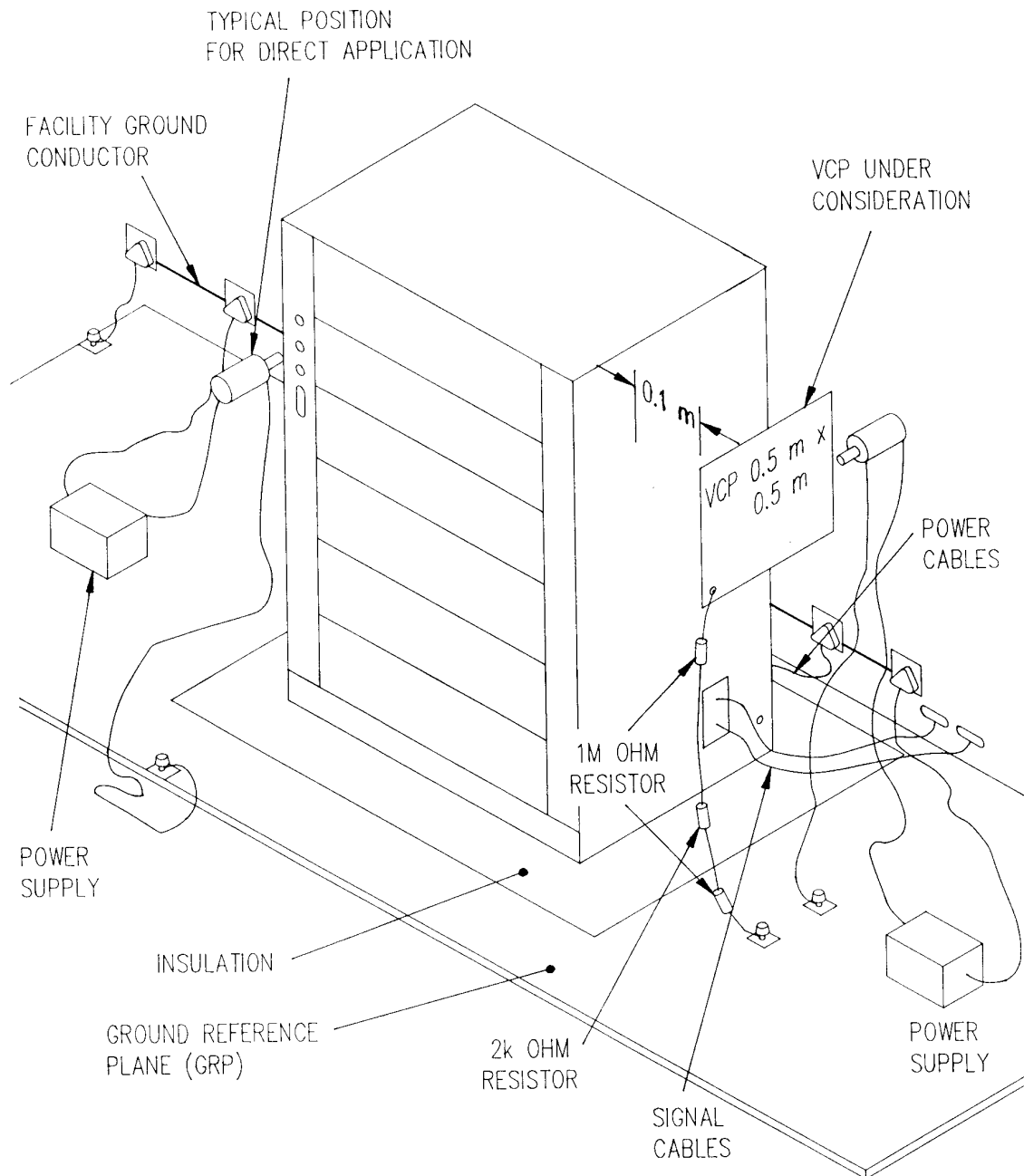


Figure 7—Test setup for floor-standing equipment—Laboratory tests

The distributed capacitance simulators are used with the following conditions:

- a) For direct ESD testing to the EUT, there is no electrical connection (or cable) between the simulator and the GRP.
- b) If the distributed capacitance simulator is used for indirect testing with a coupling plate (HCP or VCP), a bleed resistor as described in 7.5.5 should be used.
- c) The distributed capacitance simulator can be used for indirect testing by discharging the vanes to the isolated metal base holding the vanes. The crossed-vane simulator base is capacitively coupled to the GRP. A bleed resistor to the GRP is not required.
- d) Verification of the current waveform from a distributed capacitance simulator requires a bleed path between the target plane and the GRP. The setup for this verification is shown in figure 8 and described in clause 9.

NOTE—Do not use a contact-distributed capacitance simulator as an air discharge simulator unless permitted by the manufacturer. Details of a contact-distributed capacitance simulator are given in annex A.

7.4.4 VCPs/HCPs

The VCP (see annex G) and the HCP are connected to the GRP via a strap with a $1\text{ M}\Omega \pm 50\%$ high-voltage resistor located at each end. A $2\text{ k}\Omega$ low-voltage, low-wattage resistor is connected in series with the $1\text{ M}\Omega$ resistor located near the GRP. See figures 6 and 7.

NOTE—The $1\text{ M}\Omega$ resistor located at each end of the charge bleed strap shown in figures 6 and 7 should have a withstand voltage greater than 50% of the applied voltage. (The high-voltage resistor requirement is necessary to prevent breakdown creating false current loops. The $2\text{ k}\Omega$ resistor prevents the stray capacitance of the high-voltage resistor from forming a ringing circuit.)

7.5 Laboratory test procedures

Tests performed in laboratories are the preferred method of demonstrating compliance with this guide. However, unique on-site tests are allowed under the limited conditions specified in 7.6.

Clause 8 discusses the significance of multitrial testing, number of trials, and repetition rate of the discharges [B2].

7.5.1 EUT software

Choose test software for the EUT that will exercise all modes of normal operation.

Where it is cost prohibitive to exercise all normal modes of operation because of the EUT complexity, exercise either of the following:

- a) Many operating modes selected randomly
- b) Specific modes expected or known to exhibit the most susceptibility, using good engineering judgment

As the complexity of the machine operating system decreases, the probability of evaluating all or most modes of operation increases.

7.5.2 Automatic retry

When testing a product/system that has automatic retry, or specified operator intervention retry, the ESD pulse repetition rate may be adjusted, so that after a product response has occurred, at least one ESD-free product/system retry operation is allowed before another discharge is applied. This measure is necessary to allow the EUT an opportunity to clear a recoverable response should one occur. If another ESD event is permitted prior to the retry operation, the EUT would be denied this opportunity and may instead log an error requiring operator attention. Permitting the EUT one error-free operation avoids this.