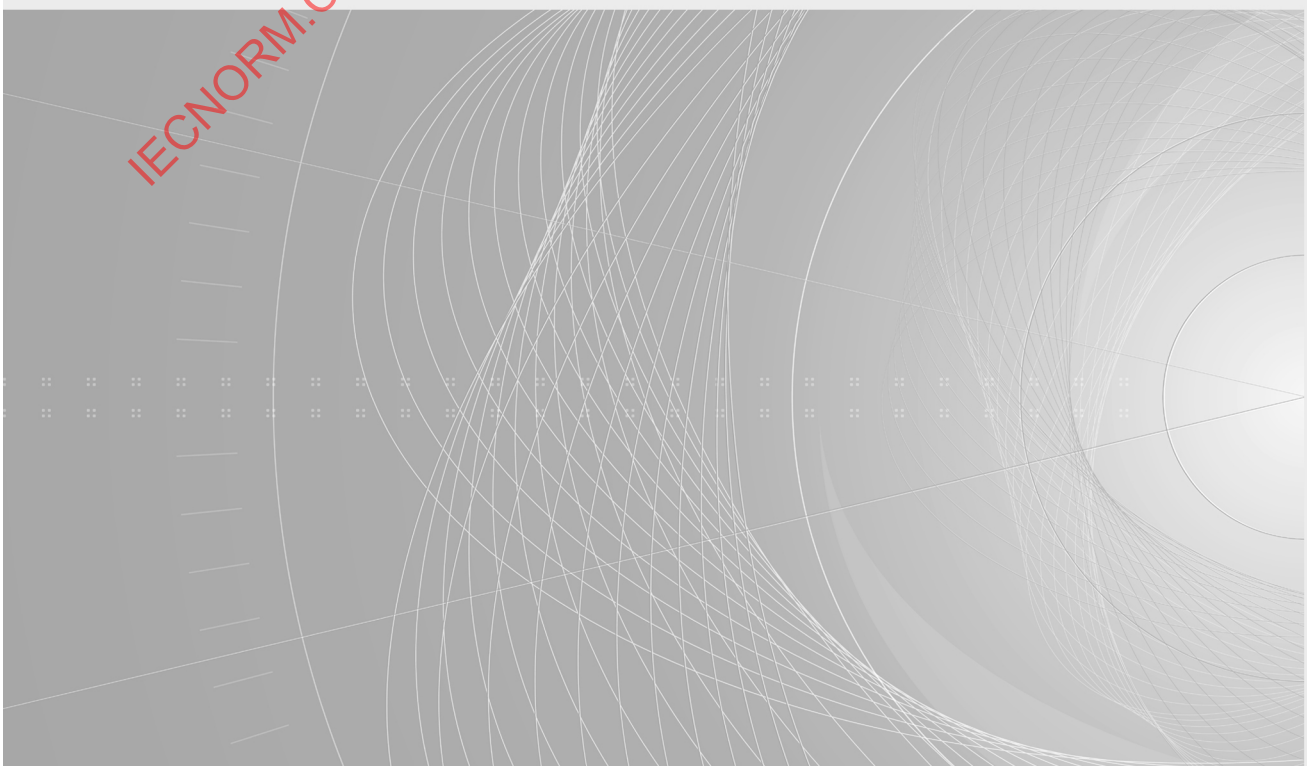
IEC TS 61340-5-4

Edition 1.0 2021-08

TECHNICAL SPECIFICATION

colour inside

Electrostatics –
Part 5-4: Protection of electronic devices from electrostatic phenomena – Compliance verification



IEC TS 61340-5-4:2021-08(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TS 61340-5-4

Edition 1.0 2021-08

TECHNICAL SPECIFICATION

colour inside

Electrostatics –
Part 5-4: Protection of electronic devices from electrostatic phenomena – Compliance verification

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 17.220.99; 29.020

ISBN 978-2-8322-1017-5

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

ELECTROSTATICS –

Part 5-4: Protection of electronic devices from electrostatic phenomena – Compliance verification

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 61340-5-4 has been prepared by IEC technical committee 101: Electrostatics. It is a Technical Specification.

This first edition cancels and replaces IEC TR 61340-5-4 published in 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TR 61340-5-4:

a) test methods in the main body of the document have been made normative, and consequently normative references have been added;
b) the term "ESD ground" has been added and defined;
c) description of equipment for measuring low resistance has been added;
d) user specified electrodes, including surface resistance bar electrodes, are permitted to be used for resistance measurements;

e) an informative annex on verification of compliance verification test equipment has been added;

f) compliance verification of person-footwear-flooring systems by measuring body voltage has been moved to an informative annex.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
101/615/DTS	101/627A/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61340 series, published under the general title *Electrostatics*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Compliance verification is the process of monitoring and measuring all elements of an ESD control program. Regular compliance verification checks and tests are an essential part of this process, ensure that area precautions and equipment remain effective, and that an ESD control program is correctly implemented in compliance with an ESD control program plan.

Qualification testing is typically carried out under controlled conditions, often in a laboratory environment, and using industry recognized standards. Compliance verification testing is carried out under operational conditions using test methods that are appropriate to a user's requirements. Although qualification test methods can be used, compliance verification testing often uses simple equipment and procedures. Accuracy is still important, but of equal importance is the ability to carry out non-destructive testing without interrupting the normal business of the organization.

This document describes equipment and test methods that can be used for compliance verification testing of ESD control items and systems, and provides users with some guidance on how to carry out the tests and take appropriate action to ensure continuous compliance.

ELECTROSTATICS –

Part 5-4: Protection of electronic devices from electrostatic phenomena – Compliance verification

1 Scope

This part of IEC 61340 describes compliance verification testing for technical items that are included in ESD control programs, such as those specified in IEC 61340-5-1.

Test methods are based on those specified in IEC 61340-5-1 and other parts of the IEC 61340 series, and are simplified where necessary for the purposes of compliance verification, to be performed by competent personnel.

Users can, by reference to this document in their compliance verification plan, adopt the necessary test methods described herein without change or addition. Alternatively, test methods described in this document can be adapted to match the requirements of their own ESD control program, provided deviations in equipment or procedure are documented in their compliance verification plan.

Compliance verification test frequency is not specified in this document. Guidance on how users can consider compliance verification test frequency is given in informative Annex A.

Product qualification is excluded from the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61340-2-3, *Electrostatics – Part 2-3: Methods of test for determining the resistance and resistivity of solid materials used to avoid electrostatic charge accumulation*

IEC 61340-4-7, Electrostatics – *Part 4-7: Standard test methods for specific applications – Ionization*

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC 62631-3-2, *Dielectric and resistive properties of solid insulating materials – Part 3-2: Determination of resistive properties (DC methods) – Surface resistance and surface resistivity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the documents listed in Clause 2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
ESD ground
terminal used to connect parts to ground for ESD control purposes

Note 1 to entry: Protective earth or functional ground may be used as ESD ground.

Note 2 to entry: Equipment ground is one form of protective earth.

4 Personnel safety

WARNING – The procedures and equipment described in this document can expose personnel to hazardous electrical conditions. Users of this document are responsible for selecting equipment that complies with applicable laws, regulatory codes and both external and internal policy. This document does not replace or supersede any requirements for personnel safety included in applicable laws, regulatory codes and both external and internal policy.

Electrical hazard reduction practices shall be exercised and proper grounding instructions for equipment shall be followed.

5 Test methods and test frequency

Test methods that are not specifically required by IEC 61340-5-1 are described in informative Annex B, Annex C, Annex D, Annex E, Annex F, Annex G and Annex H.

Compliance verification test frequency is not specified in this document. Guidance on how users should consider compliance verification test frequency is given in informative Annex A.

6 Test equipment

6.1 Selection of test equipment

If the specifications for test equipment described in Clause 6 do not match the range of measurements required to be made in the ESD control program, other test equipment that does match the range shall be used and documented in the ESD control program plan.

Test equipment shall be used and calibrated in accordance with the manufacturer's recommendations. In the absence of manufacturer's recommendations, users shall define and document suitable calibration procedures.

Annex B gives guidance on addressing known issues with test and measurement equipment.

6.2 AC outlet analyzer (or mains socket tester)

This is a device that plugs into an AC outlet and gives an indication, typically using lights, that the outlet is correctly wired, or if a fault condition exists. For compliance verification testing, an AC outlet analyzer can be used to indicate the correct wiring of the equipment grounding conductor.

Note that some AC outlet analyzers might not be able to differentiate ground (or earth and neutral wire reversals, line and neutral wire reversals, and line and ground wire reversals), or determine if the impedance to ground of the equipment grounding conductor is within the user's specification.

6.3 AC circuit tester (impedance meter)

The meter shall be capable of measuring the impedance of the equipment grounding conductor from a receptacle (power outlet used for establishing the AC equipment ground) to the neutral bond at the main service equipment panel. The meter shall also verify wiring orientation.

6.4 Charged plate monitor (CPM)

6.4.1 CPM requirements

The CPM shall meet the requirements specified in IEC 61340-4-7. The total capacitance of the test circuit, with plate, shall be (20 ± 2) pF.

In the absence of ionization, the CPM plate voltage shall not decay by more than 10 % of the initial test voltage within five minutes. The response time shall be less than 10 % of the shortest discharge time expected to be measured.

6.4.2 Portable CPM kit

Portable CPM kits for compliance verification of ionizers are commercially available and typically consist of four components: 1) electrostatic field meter or voltmeter, 2) CPM plate separated from a ground plate on insulating standoffs, 3) plate charger, and 4) ground plate. These four components may be integrated into a single instrument. A timer is used to measure discharge times.

In the absence of ionization, the CPM plate voltage shall not decay by more than 10 % of the initial test voltage within five minutes. The response time shall be less than 10 % of the shortest discharge time expected to be measured.

For convenient use in a portable CPM kit, the CPM plate is typically smaller than that specified for a CPM in 6.4.1.

A portable CPM kit that has a capacitance or plate size that differs from the CPM plate specified in 6.4.1 may be used if a correlation factor for decay and offset is established.

The plate charger shall be capable of charging the CPM plate to a voltage of each polarity in excess of the initial test voltage.

6.5 Concentric ring electrode assembly

The electrode assembly contains a central disc surrounded by a concentric ring made of conductive materials that make contact with the material under test.

The electrode assembly described in IEC 61340-2-3 meets the requirements for compliance verification testing.

6.6 Resistance measuring apparatus (ohmmeter)

The instrumentation specified in IEC 61340-2-3 for laboratory evaluations and acceptance testing have output voltages of (10,0 ± 0,5) V or (100,0 ± 5) V depending on the range of resistance being measured. Instrumentation meeting the requirements for laboratory evaluations or acceptance testing as specified in IEC 61340-2-3, or instrumentation meeting the following requirements shall be used for compliance verification testing.

Compliance verification instrumentation shall be capable of making measurements one order of magnitude above and one order of magnitude below the intended measurement range. The output voltage of compliance verification instrumentation may vary from laboratory evaluation or acceptance testing instrumentation, and may be rated under load or open circuit. Compliance

verification instrumentation shall be checked against laboratory evaluation or acceptance testing instrumentation to ensure there is correlation between measurement results.

A resistance measuring apparatus may be a single, self-contained instrument, or a combination of instruments (e.g. DC power supply, voltmeter and ammeter). If the resistance measuring apparatus has a self-switching test voltage, it shall be ensured that the changeover meets the requirements specified in IEC 61340-2-3 or specified by the user.

6.7 Low resistance meter

Resistance measuring apparatus capable of measuring less than 10^3 Ω. Compliance verification instrumentation shall be capable of making measurements one order of magnitude above and one order of magnitude below the intended measurement range. The output voltage of compliance verification instrumentation may vary from laboratory evaluation or acceptance testing instrumentation described in IEC 61340-2-3, and may be rated under load or open circuit.

6.8 Electrostatic field meter

An instrument used to measure the electric field that results from electrostatic charge on a material.

There are different types of electrostatic field meter in common use including induction probes and field mills. The relative merits of these types are discussed in IEC TR 61340-1 [1][1].

6.9 Electrostatic voltmeter

An instrument used to measure the surface potential (voltage) that results from electrostatic charge on a material. Electrostatic voltmeters shall have measurement accuracy of less than ±10 % full scale. Electrostatic voltmeters may be non-contacting or contacting. Contacting electrostatic voltmeters shall have input capacitance of less than 1×10^{-13} F and input impedance greater than 1×10^{14} Ω.

IEC TR 61340-1 [1] gives guidance on the use of different types of electrostatic voltmeters.

6.10 Footwear electrode

A conductive metal plate that is at least large enough to accommodate a person's foot, without the foot extending beyond any edge of the plate, typically 305 mm × 305 mm.

6.11 Hand-held electrode

A metal round or tubular stock (e.g. stainless steel, copper, brass), approximately 2,5 cm in diameter and 7,5 cm or greater in length, with a connector at one end. All dimensions are nominal.

6.12 Resistance measurement electrode(s)

Cylindrical electrode, (2,5 ± 0,25) kg with a diameter of (65 ± 5) mm having a contact of electrically conductive material with a Shore A hardness between 50 and 70. The resistance between two resistance measurement electrodes shall be less than $1{,}0 \times 10^3$ Ω when measured at (10,0 ± 0,5) V on a metallic surface.

The electrode described in IEC 61340-2-3 meets these specifications.

[1] Numbers in square brackets refer to the bibliography.

NOTE Over time, conductive rubber materials used as the contact surface of the electrodes can warp. This could cause measurements to change. At this time there is no standardized method to verify if this has occurred.

6.13 Insulative support surface

A planar (flat) surface, when used for specimen support, shall have a surface resistivity greater than $1{,}0 \times 10^{13}$ Ω when measured in accordance with IEC 62631-3-2 or a surface resistance or point-to-point resistance greater than $1{,}0 \times 10^{12}$ Ω or one order of magnitude greater than the item being measured in accordance with IEC 61340-2-3. The area of the insulative support surface shall be large enough to completely isolate the largest specimen intended to be tested on it.

6.14 Integrated measurement instrument for wrist strap systems or person-footwear systems

A purpose-built instrument that is used for measuring wrist strap or footwear resistance as worn.

An integrated measurement instrument for wrist strap systems shall indicate fail for resistances above the limit specified in IEC 61340-5-1, or a user defined limit.

An integrated measurement instrument for person-footwear systems shall indicate fail for resistance above the limit specified in IEC 61340-5-1, or a user defined limit.

6.15 Two-point probe

A two-point probe consists of an insulated metal body with a polytetrafluoroethylene (PTFE) insulator inserted into each end. One insulator holds test leads; the other holds receptacles that accept spring-loaded pins. The pins are gold plated and have a spring force of (4,6 ± 0,5) N. The pin tips are (3,2 ± 0,1) mm diameter electrically conductive rubber electrodes with Shore A hardness of 50 to 70. The resistance between the two resistance measurement electrodes shall be less than $1{,}0 \times 10^{3}$ Ω when measured at (10,0 ± 0,5) V on a metallic surface.

The two-point probe described in IEC 61340-2-3 meets these specifications.

6.16 User specified electrodes

Concentric ring electrode assemblies (6.5) or resistance measurement electrodes (6.12) often cannot be applied because of the size and/or shape of materials. Insufficient contact area or contact material can also result in high resistance between the electrode and the specimen. If concentric ring electrode assemblies or resistance measurement electrodes cannot be used, or if their use might result in errors, user specified electrodes may be used instead.

User specified surface resistance bar (SRB) electrodes, comprising a pair of relatively thin electrodes placed in a parallel arrangement on the surface to be tested, see Figure 18 b), can be useful for evaluating changes in resistance across different orientations, and for measuring concave or convex surfaces (e.g. cylinders).

Other user specified electrodes can include, for example, smaller concentric ring electrode assemblies, or resistance measurement electrodes of different sizes and/or shape.

When user specified electrodes are used, the following parameters shall be specified in the compliance verification plan or mentioned in the test report: shape and dimensions of the electrodes, contact force or mass of the electrodes, contact material (resistance and hardness) and distance between electrodes.

User specified electrodes can result in different measured resistance values compared to concentric ring electrode assemblies (6.5) or resistance measurement electrodes (6.12). If the user considers any such differences to be significant, acceptance limits may be adjusted accordingly and recorded in the compliance verification plan.

IEC 61340-5-1 states that if test methods are used that are different to those specified in IEC 61340-5-1, users are to show that results achieved correlate with those achieved using the referenced standards.

7 Grounding/bonding

7.1 Equipment ground and responsibility for checking systems

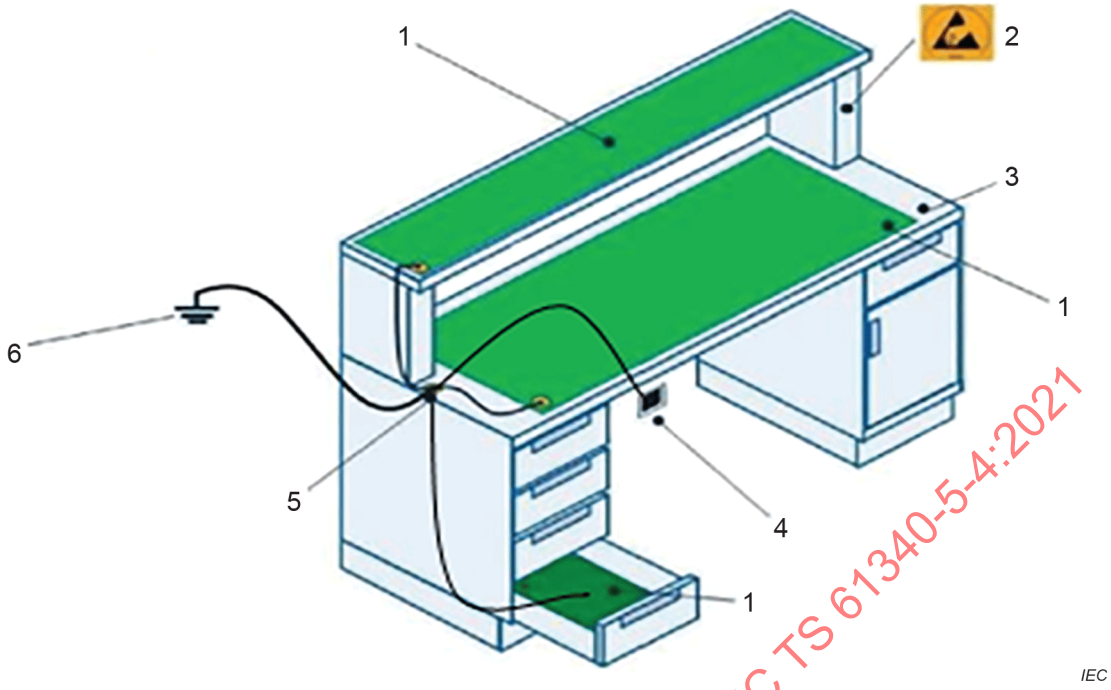
When using equipment ground as ESD ground, connection is made using a connector or adaptor approved by national electrical codes and regulations.

In many countries, national electrical codes or regulations require testing of grounding/bonding systems that include mains wiring systems to be carried out by qualified personnel.

If this is not the case in the facility then as a minimum the correct wiring shall be checked as described below. See also informative Annex I.

7.2 Objective

The objective of this compliance verification test procedure is to verify that the various grounding/bonding systems of an ESD protected area (e.g. ESD control workstation, see Figure 1) are within the resistance range allowed by the user's specification. A properly configured ESD control workstation will have all ESD control work surfaces, fixtures, handling equipment and personnel grounding devices connected to a common ground point. The common ground point is connected to the ESD ground, which in most cases will be the equipment ground (protective earth). If a functional ground is used, it shall be bonded to the electrical ground wherever possible (for information see IEC TR 61340-5-2 [2]).



Key

1 ESD control work surface (mat)
2 ESD control symbol
3 ESD control work surface
4 wrist strap bonding point
5 common ground point
6 ESD ground

Figure 1 – ESD control workstation

7.3 Test equipment

See Clause 6 for general description of test equipment.

- resistance measuring apparatus;
- two test leads of sufficient length.

7.4 Test procedure for wrist strap bonding points

- Connect two test leads to the resistance measuring apparatus.
- Connect or place one test lead to the wrist strap bonding point (personnel ground) and the other test lead to the ESD ground.
- Measure the resistance according to the instructions of the resistance measuring apparatus and note the result.

7.5 Troubleshooting wrist strap bonding point failures

- Visually and mechanically confirm that all termination hardware and grounding wires are not inadvertently loose, broken, or disconnected.
- Verify the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Test the resistance of the wrist strap bonding point to common ground point.
- Test the resistance of the common ground point to the ESD ground.

- If the measured resistance is outside the specified range, connections between the wrist strap bonding point and common ground point, and/or the common ground point and ESD ground shall be replaced and the resistance re-measured.
- If the measured resistance is still outside the specified range, the workstation shall be taken out of service and clearly marked as such.

8 Work surfaces

8.1 Basis of test procedure

This compliance verification test procedure is based on the following publication(s):

- IEC 61340-2-3;
- ANSI/ESD S6.1 [3].

8.2 Objective

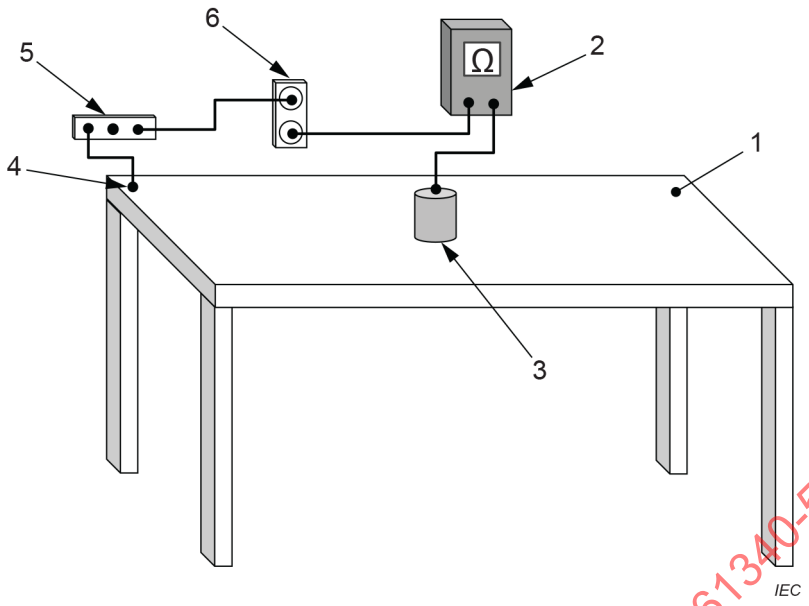
The objective of this test procedure is to verify that the ESD control work surface (a table mat or a bare table) is electrically bonded to the ESD ground and is within the minimum and maximum resistance allowed by the user's specification.

This test procedure can also be used for the measurement of shelves, drawers and other grounded ESD control storage equipment surfaces.

8.3 Test equipment

See Clause 6 for general description of test equipment.

- one resistance measurement electrode;
- two test leads of sufficient length;
- resistance measuring apparatus.



Key

1 ESD control work surface
2 resistance measuring apparatus and/or low resistance meter
3 resistance measurement electrode
4 groundable point
5 common ground point
6 ESD ground

Figure 2 – ESD control work surface test

8.4 Test procedure

- Do not clean the test surface before the verification.
- Remove all ESD sensitive items from the surface under test. All other items shall be left in place on the surface. All ground connections (including equipment ground connections) shall remain connected as the surface under test is being verified.
- Connect one end of the first test lead to the resistance measurement electrode, and the other end of the first test lead to the test instrument. See Figure 2. Connect one end of the second test lead also to the test instrument, and the other end of the second test lead to the ESD ground.
- Place the resistance measurement electrode on the surface under test.
- If a resistance measuring apparatus with automatic switching test voltage is used, make a measurement and record the resistance.
- If an automatic switching resistance measuring apparatus is not used, apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V can result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs the reading made with the 100 V test voltage is used.
- If the resistance is expected to be equal to or greater than $1{,}0 \times 10^6$ Ω the measurement with 10 V may be omitted.
- Tests shall include those surface areas that are subject to wear or are visibly dirty.

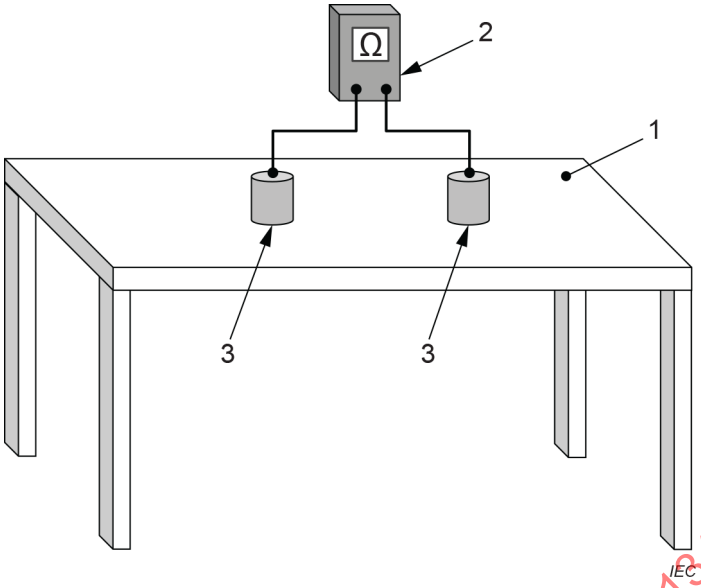
8.5 Troubleshooting

8.5.1 Visual and mechanical check

- Visually and mechanically confirm that all termination hardware and grounding wires are not loose, broken, or disconnected.
- Examine the surface and check if it is soiled or worn, which could cause increased surface resistance. If soiled, clean the surface with an approved cleaner. Ensure the surface is completely dry before retesting.
- If the measured resistance is within acceptable limits after cleaning, cleaning procedures shall be reviewed and changed as appropriate. Periodic cleaning is recommended to maintain proper electrical function of all ESD control surfaces.
- Check the connection of the mat connector to the mat.
- Check the connection of the ground cord to the mat connector.
- Check the connection of the common ground point to the ground cord.
- Check the connection of the equipment ground to the common ground point.

8.5.2 Electrical test

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Examine the resistance measurement electrode contact surface for dirt build-up. Remove surface contamination by following the manufacturer's recommendations. If using liquids to clean the electrode, allow the electrode to dry before retesting.
- With a resistance measuring apparatus, test the resistance of the surface to the groundable point.
- Over time the mechanical connection between the groundable point and the work surface might become loose. Ensure that there is a good connection between the groundable point and the work surface. With a resistance measuring apparatus or low resistance meter, test the resistance of the groundable point to the common ground point.
- With a low resistance meter, test the resistance of the common ground point to the equipment ground.
- Ensure the surface material has not deteriorated. To determine this condition, the resistance between two locations on the top of the surface (point-to-point) can be performed using a resistance measuring apparatus and two resistance measurement electrodes with test leads. See Figure 3.



Key

1 ESD control work surface
2 resistance measuring apparatus
3 resistance measurement electrodes

Figure 3 – Point-to-point resistance measurement set-up

Defective ESD control items that cannot be brought into compliance shall be taken out of service and clearly marked as such.

9 Wrist strap system

9.1 Basis of test procedure

This compliance verification test procedure is based in part on IEC 61340-4-6 [4].

9.2 Objective

The objective of this compliance verification test procedure is to verify that the total series resistance of all of the elements in the wrist strap system, including the person wearing the wrist strap, is within the minimum and maximum resistance allowed by the user's specification. For continuous monitoring of the wrist strap system, see informative Annex G.

9.3 Test equipment

See Clause 6 for general description of test equipment.

- integrated measurement instrument for wrist strap systems, or resistance measuring apparatus;
- hand-held electrode;
- one test lead of sufficient length.

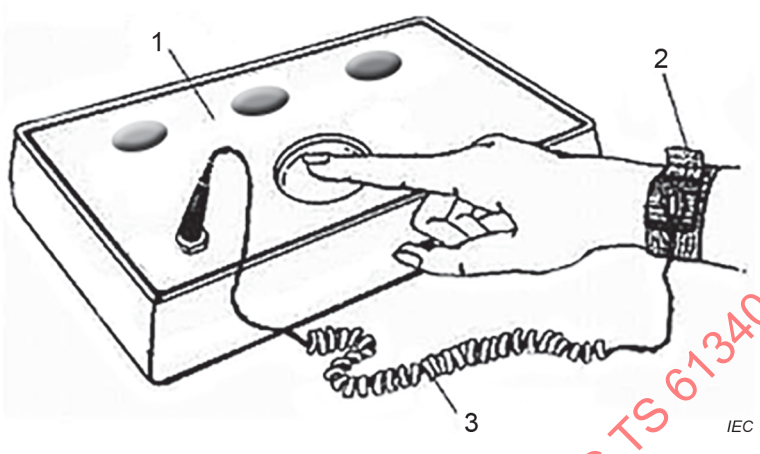
9.4 Test procedure

9.4.1 Testing with integrated measurement instrument

- Place the band on the person's wrist, attach the ground cord to the band and attach the other end of the ground cord to the integrated measurement instrument.

- Touch the contact area on the integrated measurement instrument with the finger on the hand closest to the band and activate the integrated measurement instrument following the manufacturer's instructions.

- Record the resistance or the "pass" or "fail" indication, see Figure 4.



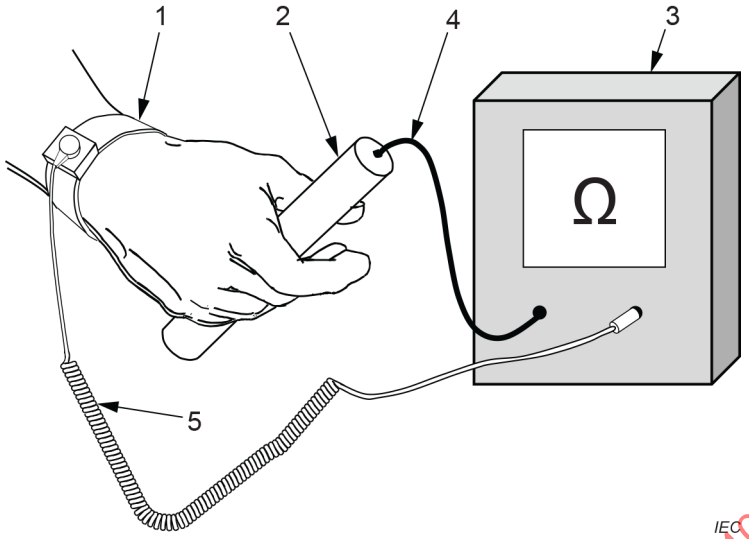
Key

1 integrated measurement instrument
2 band
3 ground cord

Figure 4 – Wrist strap test using integrated measurement instrument

9.4.2 Testing with resistance measuring apparatus

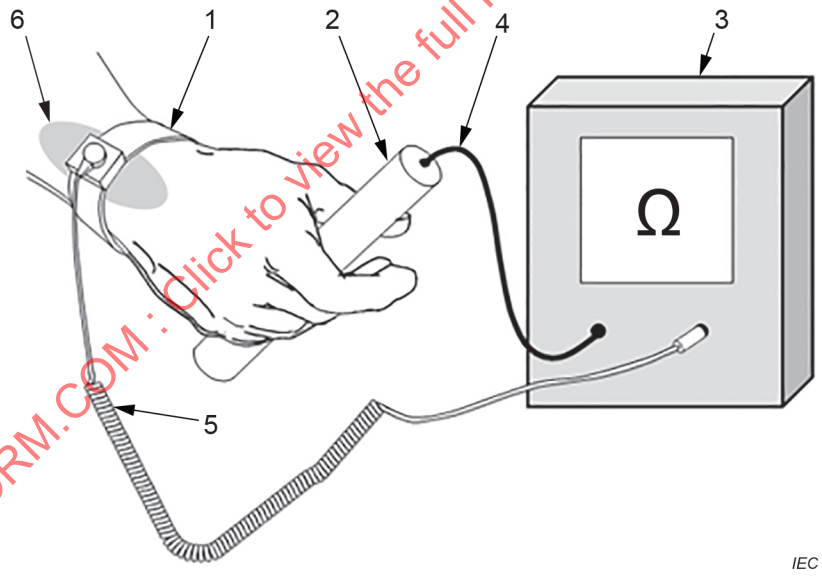
- Place the wristband with personal ground cord attached on the user's wrist in accordance with the user's procedure. Adjust the wristband if necessary, to ensure a snug fit.
- Attach the ground cord to a terminal of the resistance measuring apparatus.
- Connect one end of the test lead to the hand-held electrode and connect the other end of the test lead to the resistance measuring apparatus.
- Hold the hand-held electrode with the hand on which the wrist strap is being worn. See Figure 5.
- Measure and record the resistance of the wristband and ground cord system.
- When using a cloth wristband, it is recommended to periodically test the fabric. This can be performed by separating the buckle from the skin, for example using a thin flexible insulator, while the wristband is on the wrist, see Figure 6, or by removing the wristband from the wrist and pinching the cloth between the thumb and forefinger, see Figure 7.



Key

1 band
2 hand-held electrode
3 resistance measuring apparatus
4 test lead
5 ground cord

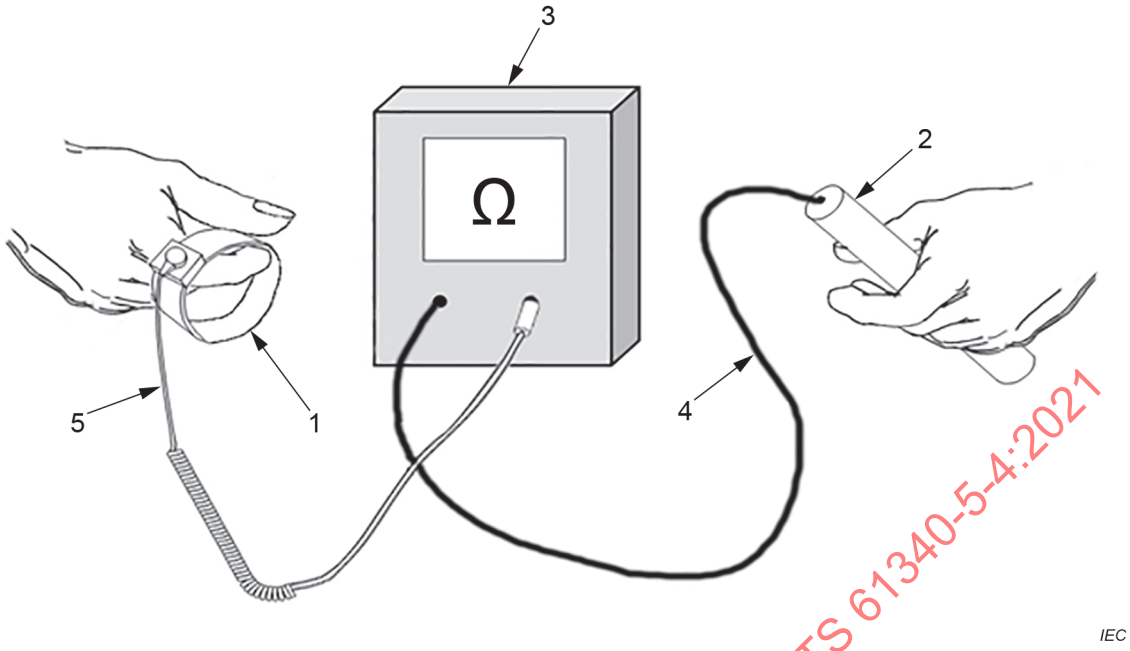
Figure 5 – Wrist strap test using resistance measurement apparatus



Key

1 band
2 hand-held electrode
3 resistance measuring apparatus
4 test lead
5 ground cord
6 thin, flexible insulator

Figure 6 – Wrist strap fabric test using resistance measuring apparatus



Key

1 band
2 hand-held electrode
3 resistance measuring apparatus
4 test lead
5 ground cord

Figure 7 – Pinched wrist strap fabric test using resistance measuring apparatus

9.5 Troubleshooting

- Verify that the test equipment is operating properly, check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Examine the wristband to ensure that it is correctly sized and adjusted snugly to the skin.
- Examine the wristband to ensure it is not soiled.
- Replace the wristband with a new wristband and repeat the test procedure.
- Replace the ground cord with a new ground cord and repeat the test procedure.
- If the steps above are not effective, the person's skin might have a high electrical resistance. Changes in weather can affect the person's skin contact resistance. Some wristbands have a propensity to trap moisture underneath the wristband and can be more effective for people with dry skin. The use of a skin lotion or gel compatible with process requirements might reduce the person's skin contact resistance. If skin lotions and gels are used, more frequent testing during the work shift might be required to ensure their continued effectiveness.

Defective ESD control items that cannot be brought into compliance shall be taken out of service and clearly marked as such.

10 Person-footwear system

10.1 Basis of test procedure

This compliance verification test procedure is based on the following publication:

- IEC 61340-5-1.

10.2 Objective

The objective of this compliance verification test procedure is to verify that the resistance of the footwear system (person and footwear only) is within the minimum and maximum resistance allowed by the user's specification. Footwear might consist of shoes, foot grounders or booties.

10.3 Test equipment

See Clause 6 for general description of test equipment.

- integrated measurement instrument for person-footwear systems, or resistance measuring apparatus;
- footwear electrode;
- hand-held electrode;
- two test leads of sufficient length.

10.4 Test procedure

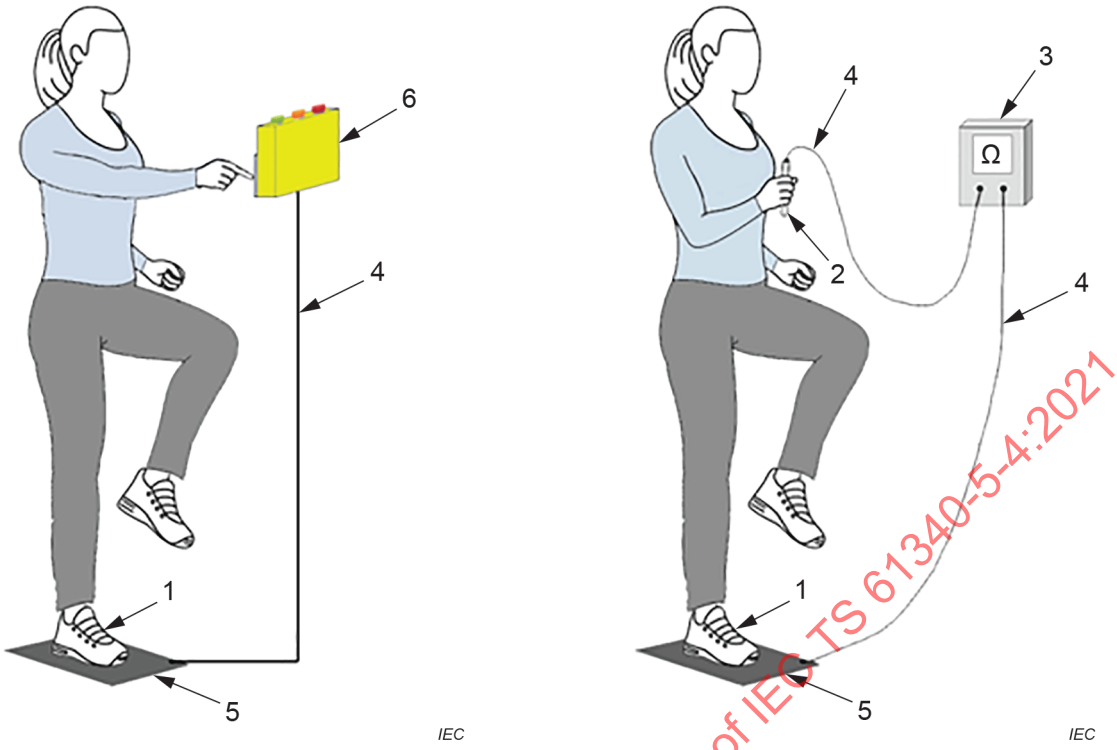
10.4.1 Testing with integrated measurement instrument

- Place the ESD footwear on feet in accordance with the user's procedure.
- Place one foot on the integrated measurement instrument's foot electrode ensuring the other foot is not in contact with the foot electrode or adjacent ESD control flooring.
- Touch the contact area on the integrated measurement instrument and activate the integrated measurement instrument. See Figure 8 a). Record the resistance or the "pass" or "fail" indication.
- Repeat for the other foot.

NOTE Some integrated measurement instruments that have dual-foot electrodes can do this measurement for both feet simultaneously.

10.4.2 Testing with resistance measuring apparatus

- Place the ESD control footwear on feet in accordance with the user's procedure.
- Connect one end of the first test lead to the hand-held electrode, and the other end of the first test lead to the resistance measuring apparatus.
- Connect one end of the second test lead to the resistance measuring apparatus, and the other end of the second test lead to the foot electrode.
- Hold the hand-held electrode with either hand.
- Place one foot on the foot electrode ensuring the other foot is not in contact with the foot electrode or adjacent ESD control flooring. See Figure 8 b).
- Apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Repeat for the other foot.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.



a) Test using integrated measurement instrument

b) Test using resistance measuring apparatus

Key

1 ESD control footwear
2 hand-held electrode
3 resistance measuring apparatus
4 test lead
5 footwear electrode
6 integrated measurement instrument for person-footwear systems

Figure 8 – ESD control footwear test

10.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Ensure the ESD control footwear is worn properly.
- Examine the ESD control footwear to ensure that its sole is not soiled or damaged, which could add resistance to the ESD control footwear system. If necessary, clean the ESD control footwear with an approved cleaner and allow the ESD control footwear to dry before retesting.
- Changes in weather and dryness of shoes can affect the person's skin contact resistance.
- People who have dry skin often take time to build up sufficient moisture in the footwear to make good contact. The use of a skin lotion or gel, compatible with process requirements, might reduce the person's skin contact resistance.
- If necessary, replace the ESD control footwear and repeat the procedure.

Defective ESD control items that cannot be brought into compliance shall be taken out of service and clearly marked as such.

11 Flooring

11.1 Basis of test procedure

This compliance verification test procedure is based on IEC 61340-4-1 [5].

11.2 Objective

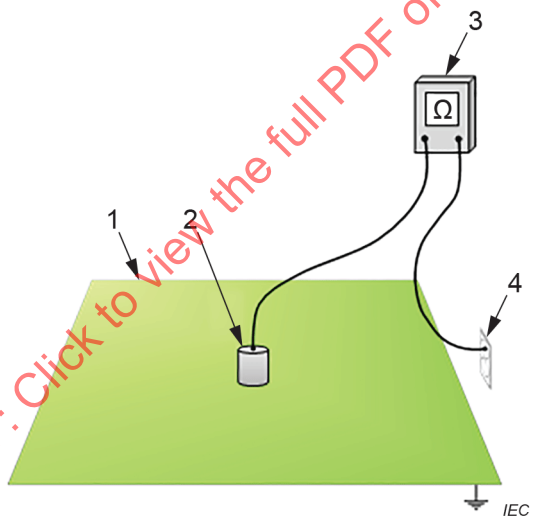
The objective of this compliance verification test procedure is to verify that the resistance to ground of the ESD control flooring is within the minimum and maximum resistance to ground allowed by the user's specification.

ESD control flooring might consist of a permanently installed floor, floor with ESD control floor finish, coatings, tiles, paints or floor mat(s).

11.3 Test equipment

See Clause 6 for general description of test equipment.

- resistance measuring apparatus;
- one resistance measurement electrode;
- two test leads of sufficient length.



Key

1 ESD control flooring
2 resistance measurement electrode
3 resistance measuring apparatus
4 ESD ground

Figure 9 – ESD control flooring test

11.4 Test procedure

- Do not clean the ESD control flooring before verification.
- Connect one end of the first test lead to the electrode, and the other end of the first test lead to the test instrument.
- Connect one end of the second test lead also to the test instrument, and the other end of the second test lead to ESD ground.
- Place the resistance measurement electrode on the floor surface. See Figure 9.

- Start with the voltage set to 10 V, wait for the meter to stabilize or for 15 s. If the value exceeds $1,0 \times 10^6$ Ω, select 100 V and repeat the measurement.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1,0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.
- Tests shall include those flooring areas that are subject to wear or are visibly dirty.

11.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Both test leads shall be capable of being isolated from ground. AC line powered resistance measuring devices might give erroneous results due to undefined ground paths.
- Examine the floor for excessive dirt or surface contamination. Remove surface contamination at the test site by following the manufacturer's recommendations. If using liquids to clean the floor, allow the flooring to dry before testing.
- Examine the resistance measurement electrode for dirt build-up. Remove surface contamination by following the manufacturer's recommendations. If using liquids to clean the electrode, allow the electrode to dry before retesting.
- Using a resistance measuring apparatus and two resistance measurement electrodes with test leads, perform a point-to-point resistance test to verify the floor material is compatible with the user's specification. If measurement results are outside the specified range, record this as a failure and continue troubleshooting. Also, if cleaning resolves the issue, this is still considered a failure and periodic cleaning shall be considered or changed.
- When measuring ESD control floor mats:
  - Check the connection of the mat fastener to the mat.
  - Check the connection of the ground cord to the mat fastener.
  - Check the connection of the common ground point to the ground cord.
  - Check the connection of the equipment ground to the common ground point.

ESD control items and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

12 Person-footwear-flooring system measurement of resistance to ground

12.1 Basis of test procedure

This compliance verification test procedure is based on the following publications:

- IEC 61340-4-5 [6];
- IEC 61340-5-1.

12.2 Objective

The objective of this compliance verification test procedure is to verify that the resistance to ground of the footwear system (person, footwear and flooring) is within the minimum and maximum resistance to ground allowed by the user's specification. The footwear might consist of shoes, foot grounders or booties. The ESD control floor might consist of a permanently installed floor, floor with ESD control floor-finish, coatings, tile, paints or floor mat(s).

12.3 Test equipment

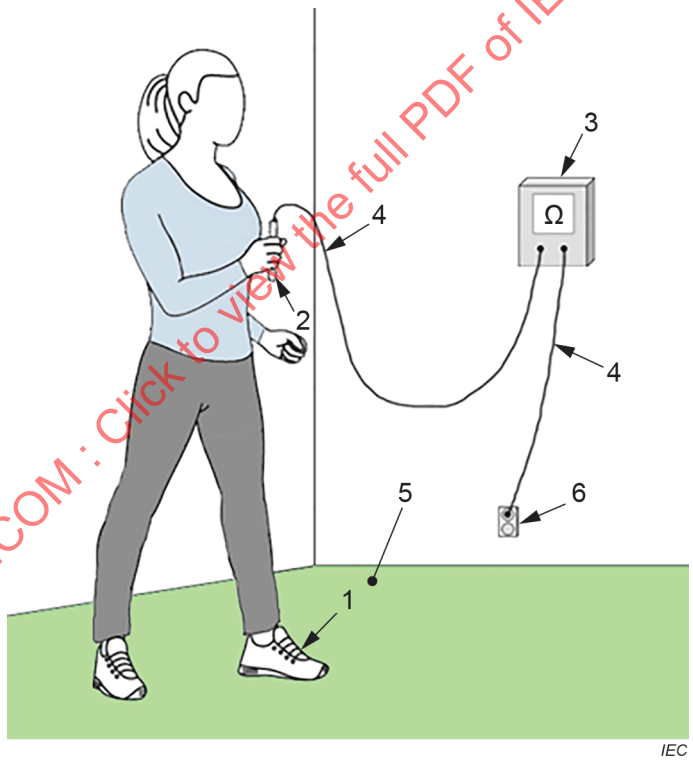
See Clause 6 for general description of test equipment.

- hand-held-electrode;
- resistance measuring apparatus;

- two test leads of sufficient length.

12.4 Test procedure

- Do not clean the ESD control floor before verification.
- Place the ESD control footwear on feet in accordance with the user's procedure.
- Connect one lead of the resistance measuring apparatus to the ESD ground.
- Connect the other lead to the hand-held electrode.
- Stand with both feet on the test floor covering and firmly grasp the hand-held electrode with either hand. See Figure 10.
- Apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Record the reading.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.
- Repeat the measurements with only the left foot in contact with the floor covering and with the right foot held in the air about 150 mm above the floor covering.
- Repeat the measurements with only the right foot in contact with the floor covering and with the left foot held in the air about 150 mm above the floor covering.



Key

1 ESD control footwear
2 hand-held electrode
3 resistance measuring apparatus
4 test lead
5 ESD control flooring
6 ESD ground

Figure 10 – Person-footwear-flooring system test

Other person-footwear-flooring system tests can be found in informative Annex D.

12.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Examine the floor for excessive dirt or surface contamination. Remove surface contamination at the test site by following the manufacturer's recommendations. If using liquids to clean the floor, allow the flooring to dry before testing.
- Ensure the ESD control footwear is worn properly.
- Examine the ESD control footwear to ensure that its sole is not soiled or damaged, which could add resistance to the ESD control footwear system. If necessary, clean the ESD control footwear with an approved cleaner and allow the ESD control footwear to dry before retesting.
- Changes in weather and dryness of shoes can affect the person's skin contact resistance. People who have dry skin often take time to build up sufficient moisture in the footwear to make good contact. The use of a skin lotion or gel, compatible with process requirements, might reduce the person's skin contact resistance.
- If necessary, replace the ESD control footwear and repeat the procedure.
- If measurement results are outside the specified range, record this as a failure and continue troubleshooting. Also, if cleaning resolves the issue, this is still considered a failure and periodic cleaning shall be considered or changed.

Defective ESD control items that cannot be brought into compliance shall be taken out of service and clearly marked as such.

13 Seating

13.1 Basis of test procedure

This compliance verification test procedure is based on IEC 61340-2-3.

13.2 Objective

The objective of this compliance verification test procedure is to verify that the resistance to ground of the chair under test is within the resistance to ground range allowed by the user's specification.

13.3 Test equipment

See Clause 6 for general description of test equipment.

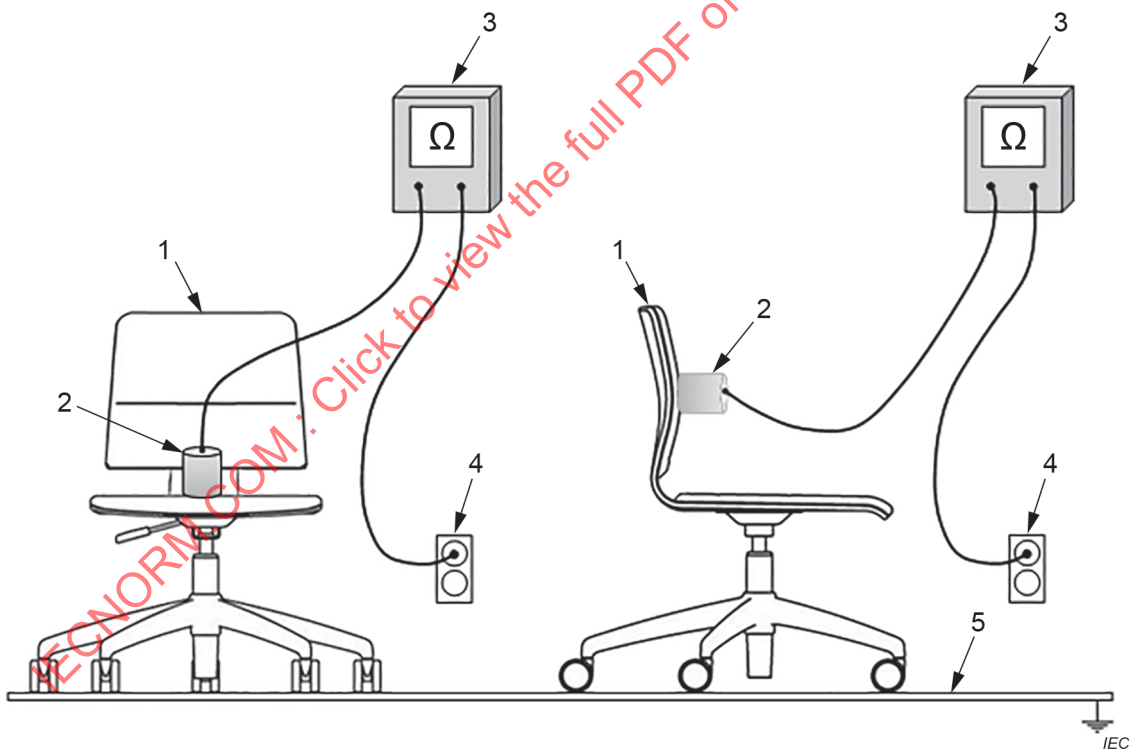
- one resistance measurement electrode;
- resistance measuring apparatus;
- two test leads of sufficient length.

13.4 Test procedure

- Place the chair under test on the installed ESD control floor. Do not clean the ESD control floor or chair immediately prior to verification.
- Connect one end of the first test lead to the resistance measurement electrode and connect the other end of the first test lead to the test instrument.
- Connect one end of the second test lead also to the test instrument and connect the other end of the second test lead to the ESD ground.
- Place or hold the resistance measurement electrode on the centre of the seat panel of the chair (place the electrode on any worn areas). See Figure 11.
- If holding the resistance measurement electrode, ensure you are not a parallel resistance path that can reduce the resistance measurement. The resistance measurement electrode shall be insulated from the operator. This may be accomplished by using either an insulative

sleeve over the resistance measurement electrode or body, or by the operator using an insulative glove or similar material. The resistance through the insulative sleeve, glove or material shall be at least ten times higher than the specified maximum limit resistance to ground.

- Apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.
- Optionally the following areas of the chair may be checked, using contact compatible electrodes appropriate to the design of the seat:
  - centre of the seat back;
  - foot ring (if so equipped);
  - arm rests (if so equipped).
- If the back of the chair backrest has a resistance to ground above the user's specification the surface shall be treated as process essential insulator (see Clause 19).
- Tests shall include those areas on the ESD control chair that are subject to wear or are visibly dirty.



Key

1 ESD control chair
2 resistance measurement electrode
3 resistance measuring apparatus
4 ESD ground
5 ESD control flooring

Figure 11 – ESD control chair test

13.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Examine the resistance measurement electrode for dirt build-up. Remove surface contamination by following the manufacturer's recommendations. If using liquids to clean the electrode, allow the electrode to dry before retesting.
- Verify the resistance of the ESD control floor surface to ESD ground. If the flooring resistance to ground is high, clean the floor with an approved cleaner. Allow the floor to dry before retesting. If the floor passes after cleaning, retest the chair. If the floor fails, go to troubleshooting in the flooring section.
- Clean the groundable point (i.e., wheels, casters, drag chain) with approved cleaner and allow drying before retesting.
- Verify that the point-to-point resistance, using two resistance measurement electrodes, or resistance to chassis of the chair's components, are compatible with the user's specification.
- Check the electrical performance of the groundable points:
  - Place one groundable point (i.e., wheels, casters, drag chain) on a conductive metal electrode and place the resistance measurement electrode on the centre of the seat panel of the chair.
  - Measure the resistance from the resistance measurement electrode to the metal electrode.
  - Repeat this test for all groundable points (i.e., wheels, casters, drag chain).
- Vacuum or clean the seat materials with manufacturer approved cleaning products (allow seat materials to dry if liquids are used) and retest.

If cleaning any of the components of the test, the floor, groundable points or fabric result in bringing the chair into compliance, a failure shall be noted and periodic cleaning shall be considered or changed.

ESD control equipment and materials that cannot be brought into compliance shall be taken out of service.

14 Air ionizers

14.1 Basis of test procedure

This compliance verification test procedure is based on IEC 61340-4-7.

14.2 Objective

The objective of this compliance verification test procedure is to verify that the discharge times and offset voltage (ion balance) of air ionizers are in compliance with the user's specification.

The test steps in this periodic test procedure are common for the following classes of ionizers: room, laminar flow hood, work surface and automated equipment (bench top and overhead), and compressed gas (gun or nozzle).

14.3 Test equipment

See Clause 6 for general description of test equipment.

- charged plate monitor or a portable CPM kit;
- a timer that is typically used to measure discharge times with portable CPM kits.

14.4 Test procedure

14.4.1 Initial test set-up

- Measurements shall be made at the location where ESD sensitive items are to be handled.
- Check that in the absence of ionization, the CPM plate, when charged to the desired voltage, does not discharge by more than 10 % of the test voltage within 5 min. Air ionizer heaters and air filters (if so equipped) shall be left in their normal conditions during the test.

14.4.2 Discharge time test

- Turn the test equipment on and allow it to stabilize in accordance with the manufacturer's recommendations.
- Momentarily ground the CPM plate and set (or verify) zero voltage.
- After the CPM plate is disconnected from ground do not zero the verification instrument in the presence of the ion field.
- Place the CPM plate in the test location.
- Charge the CPM plate to a convenient voltage in excess of the initial test voltage for each polarity (e.g., +1 200 V or −1 200 V).
- The discharge time measurement begins when the test plate voltage has decayed to the initial test voltage (typically ±1 000 V) and stops when the CPM plate voltage has decayed to the final test voltage (typically ±100 V).
- Repeat steps above for the opposite polarity. Note the discharge time in seconds for each polarity.

14.4.3 Offset voltage test (ion balance)

- Turn the test equipment on and allow it to stabilize in accordance with the manufacturer's recommendations.
- Momentarily ground the CPM plate and set (or verify) zero voltage.
- After the CPM plate is disconnected from ground do not zero the verification instrument in the presence of the ion field.
- Place the CPM plate facing the air ionizer's airflow. Wait for the reading to stabilize.
- Note the offset voltage (ion balance).

14.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Check that the test equipment is properly grounded.
- Check that there are no large conductive objects in the area that could cause ion attraction to their surface.
- Increase air speed when decay time is out of the user's specified limit.
- Check that items in the work area are not blocking the airflow and that other sources of airflow are not affecting the area.
- Check fans for proper operation.
- Check air filters for clogging with dust and dirt. Clean or replace air filter as necessary.
- After removing electrical power, check emitter points (they shall be clean and not bent or broken). Clean or replace if necessary, following the manufacturer's instructions. Allow emitter points to dry before retesting.
- Check electrical equipment grounds for grounding integrity.
- If applicable, adjust the offset voltage (ion balance) of the ionizer following the manufacturer's instructions.

- If applicable, check alpha radiation sources for service life date. Replace if necessary, following the manufacturer's instructions.
- If applicable, check the alpha source's case to ensure it is properly grounded in accordance with the manufacturer's instructions.

If cleaning or replacing any of the components of the test, the filters or emitter point result in bringing the ionizer into compliance, a failure shall be noted and periodic cleaning shall be considered or changed.

Defective ESD control equipment and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

15 Mobile equipment

15.1 Basis of test procedure

This compliance verification test procedure is based on the following publications:

- IEC TR 61340-5-2 [2];
- ANSI/ESD S6.1 [3];
- ANSI/ESD ADV 53.1 [7];
- IEC 61340-2-3.

15.2 Objective

The objective of this compliance verification test procedure is to verify the resistance of the mobile equipment (such as cart or trolley) grounding system (mobile equipment through grounded floor) is within the minimum and maximum resistance allowed by the user's specification.

All possible work surfaces of mobile equipment that are grounded with a ground cord shall be tested in accordance with Clause 8.

15.3 Test equipment

See Clause 6 for general description of test equipment.

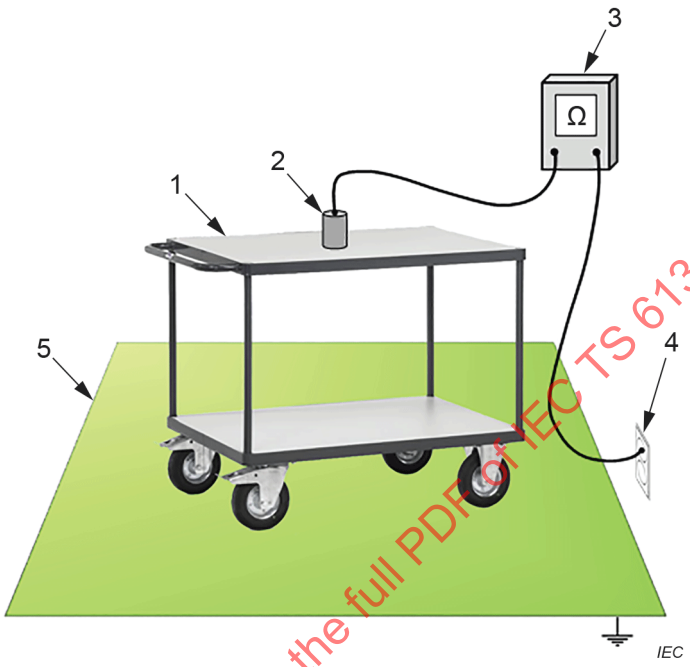
- resistance measuring apparatus;
- resistance measurement electrode;
- two test leads of sufficient length.

15.4 Test procedure

- Place the mobile equipment on a grounded ESD control flooring.
- Do not clean the ESD control floor immediately prior to verification.
- Remove all ESD sensitive items from the mobile equipment.
- Connect one end of the first test lead to the resistance measurement electrode, and the other end of the first test lead to the resistance measuring apparatus.
- Connect one end of the second test lead also to the resistance measuring apparatus, and the other end of the second test lead to the ESD ground.
- Place the resistance measurement electrode on the centre of the top mobile equipment work surface. See Figure 12.
- Apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than

$1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.

- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.
- Repeat the procedure for all other work surfaces of the mobile equipment.
- Tests shall include those areas on the mobile equipment that are subject to wear or are visibly dirty.



Key

1 ESD control mobile equipment
2 resistance measurement electrode
3 resistance measuring apparatus
4 ESD ground
5 ESD control flooring

Figure 12 – ESD control mobile equipment test

15.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Verify that the floor resistance to ground meets the user's defined requirements.
- Verify the components of the cart are not electrically isolated.
- Visually check to ensure that the groundable point(s) (such as drag chain, cables, casters, wheels) used to ground the mobile equipment to the floor are not soiled and are attached securely (clean accordingly, if necessary).
- Examine the grounding connections of the mobile equipment working surfaces.
- Examine the groundable point(s) on the mobile equipment to ensure that they are not soiled or worn, which could add resistance to the mobile equipment grounding system. If soiled, clean the groundable point(s) on the mobile equipment with an approved cleaner, and repeat the procedure.
- Check the electrical performance of the groundable point(s):

  - Place one groundable point (i.e., wheels, casters, drag chain) on a conductive metal electrode and place the resistance measurement electrode on the centre of the top of the mobile equipment working surface.
  - Measure the resistance from the resistance measurement electrode to the metal electrode.
  - Repeat for all other groundable points.
- Examine the resistance measurement electrode for dirt build-up. Remove surface contamination by following the manufacturer's recommendations. If using liquids to clean the electrode, allow the electrode to dry before retesting.
- Measure again the resistance from the resistance measurement electrode to the metal electrode.
- Drag chains or cables have been known to be unreliable for grounding mobile equipment (see IEC TR 61340-5-2 [2]). When making measurements on mobile equipment, a situation might occur where the initial result is outside the acceptable limits but a subsequent result after moving the equipment slightly is within the acceptable limits. In this case, it is recommended that further measurements be made to determine if the out-of-limits measurement can be treated as an outlier.

If cleaning any of the components of the test, the floor, groundable points, mobile equipment working surfaces, result in bringing the mobile equipment into compliance a failure shall be noted and periodic cleaning shall be considered or changed.

ESD control equipment and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

16 Groundable static control garment system

16.1 Basis of test procedure

This compliance verification test procedure is based on the following publications:

- IEC 61340-4-6 [4];
- IEC 61340-4-9 [8].

16.2 Objective

The objective of this compliance verification test procedure is to verify that the total series resistance of all of the elements (including ground cord) in the groundable static control garment system is within the minimum and maximum resistance allowed by the user's specification.

A groundable static control garment system is a groundable static control garment that establishes an electrical bonding path for a person wearing the garment to the groundable point on the garment.

A groundable static control garment system provides a ground path for a person that not only suppresses the electrical field from clothing worn underneath the garment and dissipates triboelectrically generated surface charge, but also bonds the skin of the wearer to an identified ground path. Groundable static control garment systems might also be used in conjunction with a continuous or constant monitoring system in a manner similar to those used in continuous monitoring of wrist straps in an ESD protected area (EPA).

ESD control garments might consist of clean room frocks, clean room coveralls, lab coats, jackets, and smocks.

16.3 Test equipment

See Clause 6 for general description of test equipment.

Resistance measuring apparatus or integrated measurement instrument for wrist strap systems, which shall give a pass or fail indication corresponding to the limits specified in the compliance verification plan.

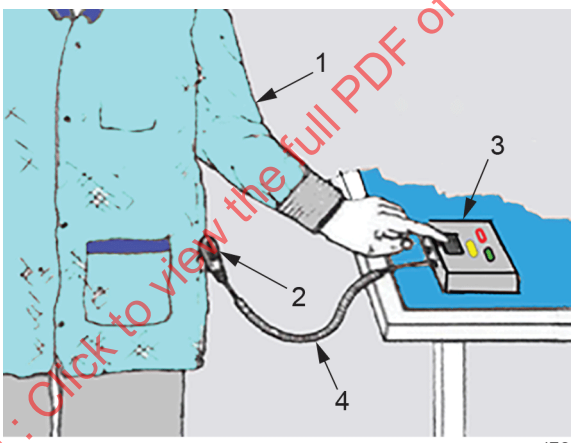
NOTE Some integrated measurement instruments require the manual selection of wrist strap system resistance test ranges.

- hand-held electrode;
- two test leads of sufficient length.

16.4 Test procedure

16.4.1 Testing with integrated measurement instrument

- Put on a garment and properly fasten it in accordance with the user's procedure. Ensure the garment cuffs are snug to the skin. If adjustable cuffs are used, adjust to ensure a snug fit. Attach the ground cord to the garment's ground cord connection.
- If applicable, switch the wrist strap system or footwear integrated measurement instrument to the wrist strap system setting.
- Insert or attach the loose end of the ground cord into the integrated measurement instrument.
- Press and hold the metal contact or test plate with either hand until the pass or fail indication is shown. See Figure 13.



Key

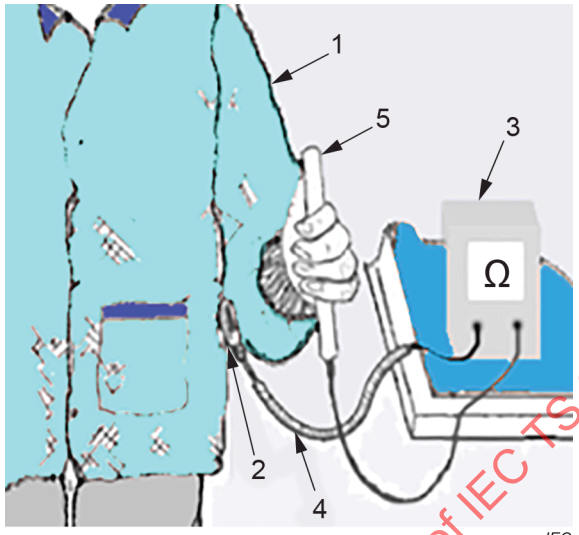
1 groundable static control garment system
2 groundable point
3 integrated measurement instruments
4 ground cord

Figure 13 – Testing groundable static control garment system in combination with a person using an integrated measurement instrument

16.4.2 Testing with resistance measuring apparatus

- Put on a garment and properly fasten it in accordance with the user's procedure. Ensure the garment cuffs are snug to the skin. If adjustable cuffs are used, adjust to ensure a snug fit.
- Attach the ground cord to the garment's groundable point.
- Connect the loose end of the ground cord to the meter.
- Connect one end of the other test lead to the hand-held electrode and connect the other end of the test lead to the meter.
- Hold the hand-held electrode with either hand. See Figure 14.

- Apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.



Key

1 groundable static control garment system
2 groundable point
3 resistance measuring apparatus
4 ground cord
5 hand-held electrode

Figure 14 – Test set-up – Groundable garment in combination with a person, hand-held probe and resistance measurement apparatus

16.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Examine the garment cuff to ensure that it is correctly sized and adjusted to be snug to the skin with no intervening clothing or other items.
- Examine the garment and cuff area to ensure it is not soiled or torn.
- If the steps above are not effective, the person's skin might have a high electrical resistance. Changes in weather can affect the person's skin contact resistance. The use of a skin lotion or gel compatible with process requirements might reduce the person's skin contact resistance around the cuff area. If skin lotions and gels are used, more frequent testing during the work shift might be required to ensure their continued effectiveness.
- Examine the seams between panels to ensure they are not soiled or torn.
- Replace the ground cord with a new ground cord and repeat the procedure.
- Replace the garment with a new garment and repeat the procedure.

ESD control equipment and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

17 Static control garments and groundable static control garments

17.1 Point-to-point test method

17.1.1 Basis of test procedure

This compliance verification test procedure is based on IEC 61340-4-9 [8].

17.1.2 Objective

The objective of this compliance verification test procedure is to verify that the sleeve-to-sleeve (or cuff-to-cuff) resistance of garments is within the minimum and maximum resistance allowed by the user's specification.

ESD control garments might consist of clean room frocks, clean room coveralls, lab coats, jackets, and smocks.

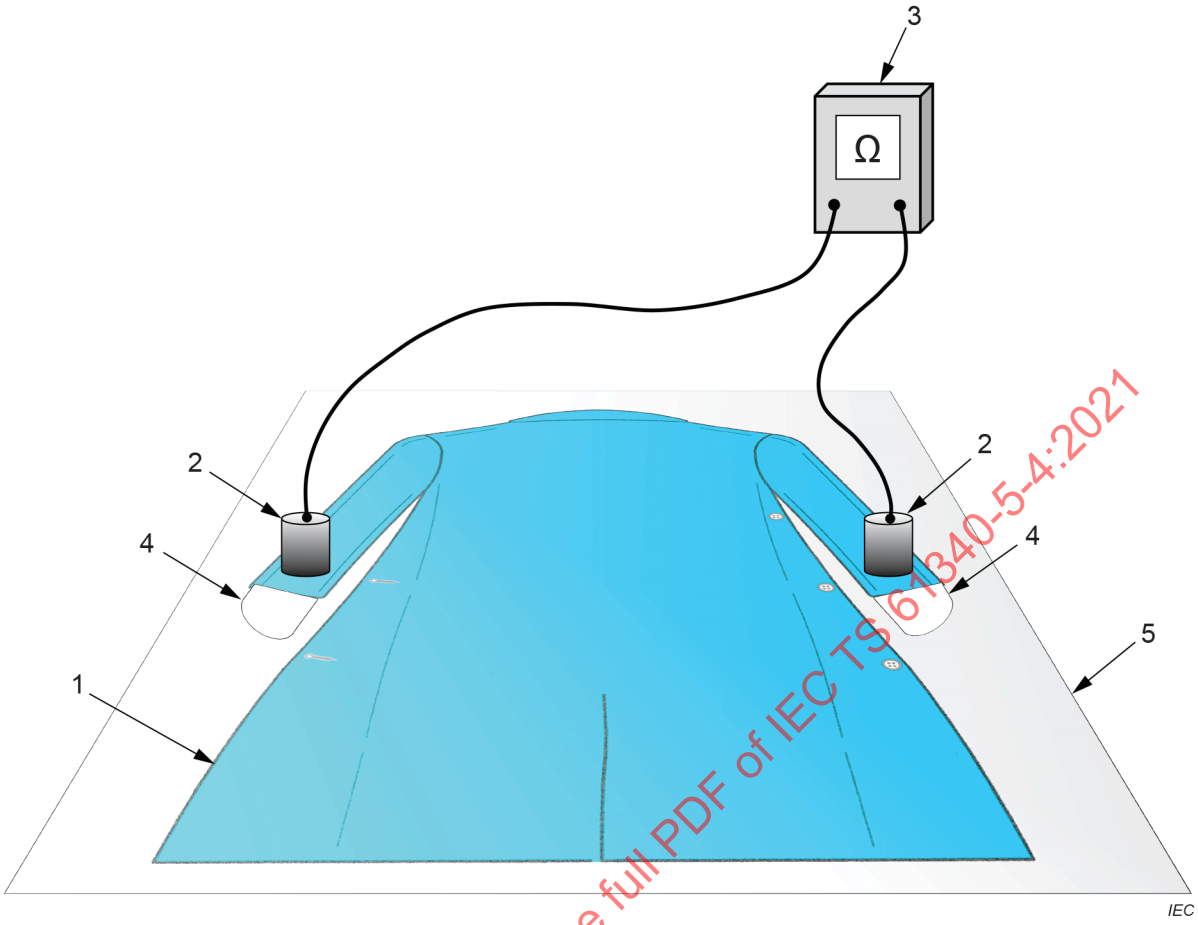
17.1.3 Test equipment

See Clause 6 for general description of test equipment.

- resistance measuring apparatus;
- two resistance measurement electrodes;
- two test leads of sufficient length;
- two insulative sleeve inserts (sufficiently large enough for garments).

17.1.4 Test procedure

- Connect the two resistance measurement electrodes to the test leads and connect the test leads to the integrated resistance measuring apparatus.
- Place the garment opened as much as possible flat on the insulative support surface. It is important to open the garment to avoid any connections between panels that are not present when the garment is being worn.
- Insert the insulative sleeve inserts into the end of each sleeve. See Figure 15.
- Set the resistance measurement electrodes on each sleeve (or each cuff) of the garment. Ensure the sleeves are separated from the body of the garment. See Figure 15.
- Apply 10 V and wait for the meter to stabilize or for 15 s. If the indicated resistance is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the indicated resistance is equal to or greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.



Key

1 static control garment or groundable static control garment
2 resistance measurement electrode
3 resistance measuring apparatus
4 insulative sleeve insert
5 insulative support

Figure 15 – Garment (point-to-point) test

17.1.5 Troubleshooting

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Examine the resistance measurement electrodes for dirt build-up. Remove surface contamination by following the manufacturer's recommendations. If using liquids to clean the electrodes, allow the electrodes to dry before retesting.
- Examine the garment (e.g., seams between panels) to ensure it is not soiled or torn.
- Review laundry process:
  - High temperatures from washing, drying or ironing might damage the carbon fibres in the garment.
  - Fabric softeners used in the laundry process might coat the fibres.
  - Chlorine bleach might damage conductive fibres (especially silver based fibres).
  - Some garments, typically from rental suppliers, can require topical finishes or treatments to be re-applied after washing, either in the final rinse or as a separate process.

Defective ESD control equipment and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

17.2 Hanging clamp method

17.2.1 Basis of test procedure

This compliance verification test procedure is based on IEC 61340-4-9 [8].

17.2.2 Objective

The objective of this compliance verification test procedure is to verify that the sleeve-to-sleeve (or cuff-to-cuff) resistance of garments is within the minimum and maximum resistance allowed by the user's specification.

ESD control garments might consist of clean room frocks, clean room coveralls, lab coats, jackets, and smocks.

17.2.3 Test equipment

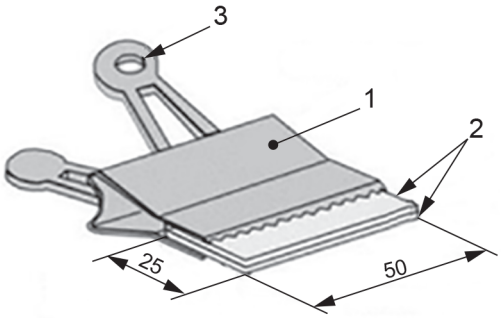
See Clause 6 for general description of test equipment.

- resistance measuring apparatus;
- insulative hanging apparatus (meeting the electrical requirements of the insulative support surface);
- two clamp electrodes. See Figure 16;
- two test leads of sufficient length.

17.2.4 Test procedure

- Use an insulative hanging apparatus to hang the garment from each sleeve with electrically isolated clamp electrodes.
- Clamp electrodes shall be attached as follows:
  - for garments equipped with cuffs, attached to the cuffs;
  - for garments not equipped with cuffs, attached to the sleeves.
- The resistance measurement shall be made by applying the voltage lead to one clamp and attaching the sensor lead to the other clamp. See Figure 17.
- Apply 10 V and wait for the meter to stabilize or for 15 s if the reading is less than $1{,}0 \times 10^6$ Ω, note the resistance. If the reading is greater than or equal to $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.

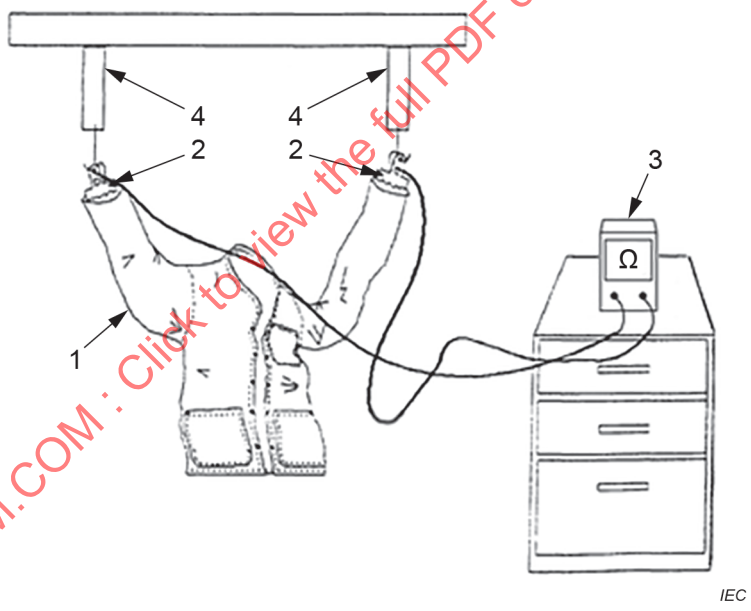
Dimensions in millimetres



Key

1 electrically conductive clamp
2 electrode, e.g. stainless steel
3 test lead connection

Figure 16 – Electrodes for hanging garment test



Key

1 static control garment or groundable static control garment
2 clamps
3 resistance measuring apparatus
4 insulators

Figure 17 – Hanging clamp resistance measurement

17.2.5 Troubleshooting

Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.

- Examine the electrodes for dirt build-up. Remove surface contamination by following the manufacturer's recommendations. If using liquids to clean the electrodes, allow the electrodes to dry before retesting.
- Examine the garment (e.g., seams between panels) to ensure it is not soiled or torn.
- Review laundry process:
  - High temperatures from washing, drying or ironing might damage the carbon fibres in the garment.
  - Fabric softeners used in the laundry process might coat the fibres.
  - Chlorine bleach might damage conductive fibres (especially silver based fibres).
  - Some garments, typically from rental suppliers, can require topical finishes or treatments to be re-applied after washing, either in the final rinse or as a separate process.

Defective ESD control equipment and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

Other test methods for garments can be found in informative Annex C.

18 Packaging

18.1 Basis of test procedure

This compliance verification test procedure is based on the following publications:

- IEC TR 61340-1 [1];
- IEC 61340-2-3;
- IEC 61340-5-3 [9].

18.2 Objective

The objective of this compliance verification test procedure is to verify the surface or volume resistance of ESD control packaging that is used in the manufacturing process. ESD control packaging might consist of waffle packs, bags, totes, bins, and storage boxes, trays, cushion wrap, foam, tubes, tape and reel, shrink-wrap, and any other material used to facilitate in-process material handling.

A well-designed compliance verification program addresses ESD control packaging because the static control properties of many types of packaging might deteriorate with time and use. These tests cannot be used for shielding effectiveness or energy penetration.

If packaging is used as a work surface the requirements of work surfaces shall be applied.

18.3 Test equipment

See Clause 6 for general description of test equipment.

- resistance measuring apparatus;
- insulative support surface;
- one or more of the following electrodes:
  - concentric ring electrode assembly;
  - two surface resistance bar (SRB) electrodes or other user specified electrodes;
  - two-point probe;
  - two resistance measurement electrodes;
- conductive metal electrode, the area shall be slightly greater than the packaging under test.

The electrodes and resistance measuring apparatus may be combined into a single integrated resistance measuring instrument.

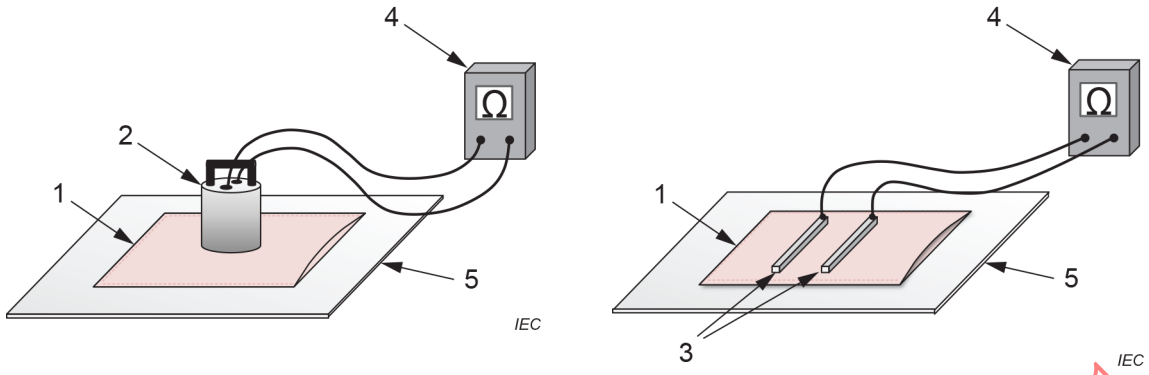
18.4 Test procedure

18.4.1 Surface resistance using an integrated resistance measuring instrument

- Place the packaging on the insulative support surface to ensure making measurements that concur with product qualification or acceptance testing data. Measurement on dissipative or conductive surfaces will tend to bias the measurements and might provide erroneous results.
- Caution is needed when using the insulative specimen support surface for testing inside of an active EPA. All ESDS items shall be moved a distance greater than 30 cm from the testing area.
- Place test electrodes of the integrated resistance measuring instrument near the centre of the packaging (or on worn areas).
- Apply the test voltage and observe the reading, or if the test voltage can be selected as 10 V or 100 V, first apply 10 V and wait for the meter to stabilize or for 15 s. If the reading is greater than $1,0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1,0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.
- Surface resistance of visually identical packaging can vary by many orders of magnitude. To avoid possible damage to measuring instruments or samples, measurements should always be made first with the test voltage set to 10 V.
- If testing bag materials, the inside surface as well as the outside shall be tested for surface resistance properties.

18.4.2 Surface resistance using a concentric ring electrode assembly or two SRBs

- Place the packaging on the insulative support surface. Measurement on dissipative or conductive surfaces will tend to bias the measurements and might provide erroneous results.
- Place the concentric ring electrode assembly or two SRBs near the centre of the packaging (or on worn areas). See Figure 18.
- Connect the resistance measuring apparatus to the electrodes.
- Apply 10 V and wait for the meter to stabilize or for 15 s. If the reading is greater than $1,0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1,0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.



a) Test using concentric ring electrode assembly **b) Test using surface resistance bar electrodes**

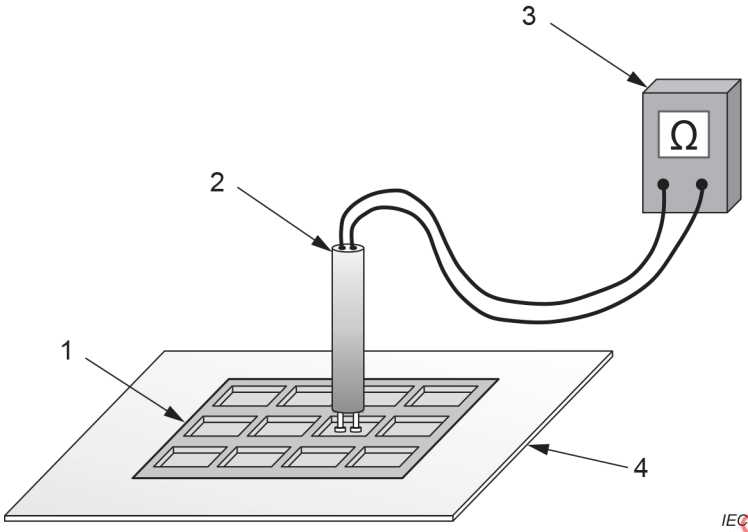
Key

1 ESD control packaging
2 concentric ring electrode assembly
3 surface resistance bar electrodes
4 resistance measuring apparatus
5 insulative support

Figure 18 – Set-up for test method using concentric ring electrode assembly and surface resistance bar electrodes

18.4.3 Surface resistance using a resistance measuring apparatus and two-point probe

- Place the packaging on the insulative support surface. Measurement on dissipative or conductive surfaces will tend to bias the measurements and might provide erroneous results.
- Caution is needed when using the insulative specimen support surface for testing inside of an active EPA. All ESDS items shall be moved a distance greater than 30 cm from the testing area.
- Place the test electrodes near the centre of the packaging (or on worn areas). It also is appropriate to place the probe into recessed areas as needed. See Figure 19.
- Connect the resistance measuring apparatus to the electrodes.
- Apply 10 V and wait for the meter to stabilize or 15 s. If the reading is greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.



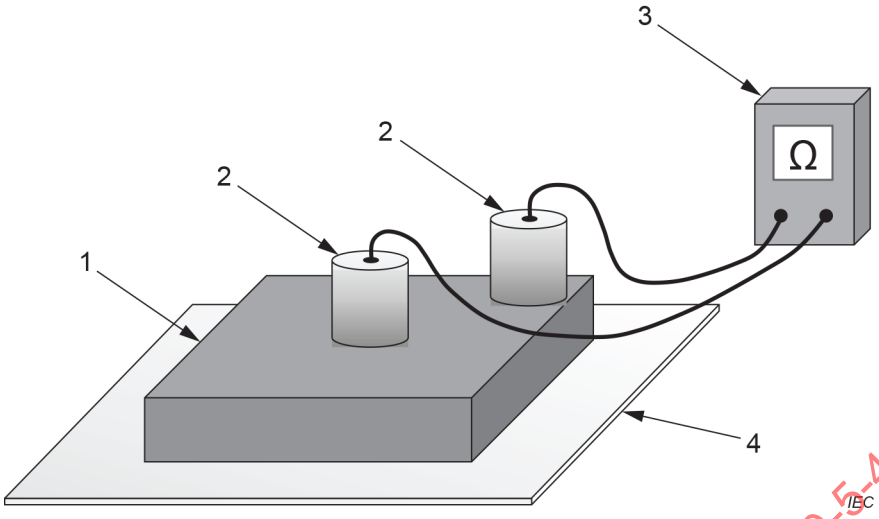
Key

1 typical ESD control packaging: precision tray
2 two-point probe
3 resistance measuring apparatus
4 insulative support

Figure 19 – Set-up for test method using a resistance measuring apparatus and two-point probe

18.4.4 Point-to-point resistance using a resistance measuring apparatus and resistance measurement electrodes

- Place the packaging on the insulative support surface. Measurement on dissipative or conductive surfaces will tend to bias the measurements and might provide erroneous results.
- Place one electrode near the centre of the packaging (or on worn areas) and the second electrode on one corner (or as near as possible to one corner). See Figure 20.
- Connect the resistance measuring apparatus to the resistance measurement electrodes.
- Apply 10 V and wait for the meter to stabilize or 15 s. If the reading is greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.



Key

1 ESD control packaging

2 resistance measurement electrodes

3 resistance measuring apparatus

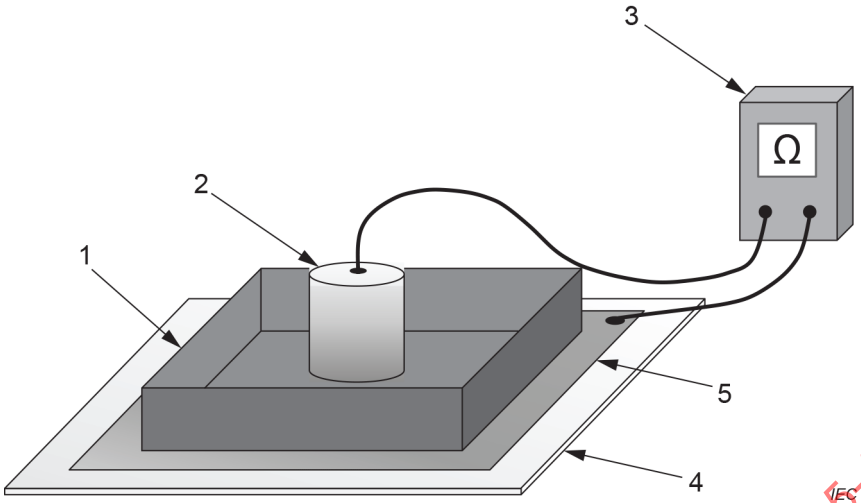
4 insulative support

Figure 20 – Set-up for test method using two resistance measurement electrodes

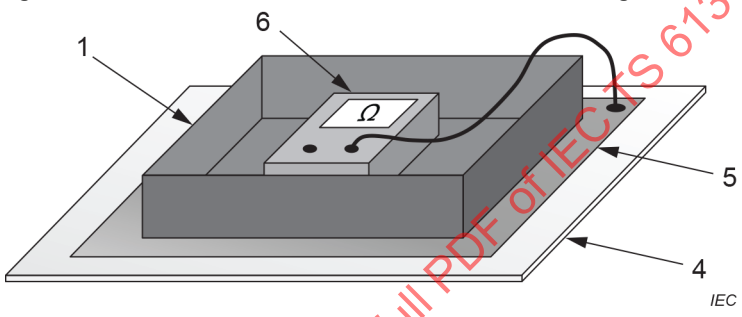
18.4.5 Volume resistance using resistance measuring apparatus or integrated resistance measuring instrument

NOTE This procedure can only be used for volume conductive or dissipative packaging.

- Place the conductive electrode onto the insulative support surface and place the ESD control packaging on the conductive electrode.
- Place the resistance measurement electrode, concentric ring electrode or integrated resistance measuring instrument in the centre of the ESD packaging. See Figure 21. Some integrated resistance measuring instruments have two electrodes (bars or concentric rings) and both remain connected to the measuring circuit of the instrument. Such instruments cannot be used for this procedure.
- Volume resistance can be measured with an integrated resistance measuring instrument only if one of the electrodes can be disconnected from the measuring circuit.
- Apply the test voltage and observe the reading, or if the test voltage can be selected as 10 V or 100 V, first apply 10 V and wait for the meter to stabilize or for 15 s. If the reading is greater than $1{,}0 \times 10^6$ Ω, switch the meter to 100 V and retest. Note the resistance after the meter stabilizes or after 15 s.
- Switching the test voltage to 100 V might result in a resistance reading of less than $1{,}0 \times 10^6$ Ω. When this occurs, the reading made with the 100 V test voltage is used.
- Surface resistance of visually identical packaging can vary by many orders of magnitude. To avoid possible damage to measuring instruments or samples, measurements should always be made first with the test voltage set to 10 V.



a) Test using resistance measurement electrode or concentric ring electrode assembly



b) Test using integrated resistance measuring instrument

Key

1 ESD control packaging
2 resistance measurement electrode or concentric ring electrode with only the inner contact connected
3 resistance measuring apparatus
4 insulative support
5 conductive electrodes
6 integrated resistance measuring instrument

Figure 21 – Set-up for test method using resistance measurement electrode or concentric ring electrode assembly and integrated resistance measuring instrument

18.5 Troubleshooting (surface, point-to-point and volume resistance)

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- If the tester reads open circuit, check the wires for continuity and connections to terminations.
- When measuring packaging with high resistance values, the test wires might pick up interference (line voltage, noise, etc.) causing measurement problems. Move the test set-up to an area with less interference.
- Check the relative humidity of the area. A reduction in humidity could cause an increase in the volume resistance of some packaging.

Defective ESD control equipment and materials that cannot be brought into compliance shall be taken out of service and clearly marked as such.

NOTE Packaging with coated surfaces might lose their static control properties if washed or subjected to other chemicals.

19 Process essential insulators

19.1 Basis of test procedure

The use of electrostatic field meters and electrostatic voltmeters are referenced in the following publications:

- IEC TR 61340-1 [1];
- IEC TR 61340-5-2 [2].

19.2 Objective

The objective of this compliance verification test procedure is to verify that process essential insulators do not exceed the maximum electrostatic field strength or surface potential allowed by the user's specification.

When making measurements on process essential insulators, it is important to take account of any charging mechanisms (contact and separation processes, rubbing, etc.) that might charge the insulators, and to replicate those processes as closely as possible before making measurements.

NOTE IEC 61340-5-1 requires that non-essential insulators are removed from the process environment.

19.3 Test equipment

See Clause 6 for general description of test equipment.

- electrostatic field meter or electrostatic voltmeter.

19.4 Test procedure

19.4.1 Measuring electrostatic field strength at the site of the ESD sensitive device (ESDS) from electrostatic field source

The electrostatic field at the possible positions of the ESDS is measured using an electrostatic field meter.

- Ground the field meter (some field meters can be grounded via a grounded person holding the case).
- Operate the electrostatic field meter in accordance with the manufacturer's instructions, including any procedures for zeroing.
- Position the field meter at a typical possible position of the ESDS closest to the electrostatic field source.
- Allow the meter to stabilize.
- Record the meter reading.

Some materials or objects in contact with or near a non-insulating surface might exhibit field suppression and show a lowered level of electrostatic field. If the item remains in that position, the field reading found can be considered realistic. If the item moves away from that position during normal operations, the field might increase considerably. In this case further measurements shall be made with the item positioned away from the non-insulating surface.

19.4.2 Measurement of surface voltage of a process essential insulator

- Ground the electrostatic voltmeter (some meters can be grounded via a grounded person holding the case).
- Zero the meter in accordance with the manufacturer's instructions if required.

- Position the electrostatic voltmeter at the correct distance from the surface to be measured in accordance with the manufacturer's instructions.
- Allow the reading to stabilize and then record the reading.

Some materials or objects in contact with or near a non-insulating surface might exhibit field suppression and show a lowered level of surface voltage. If the item remains in that position, the voltage reading found can be considered realistic. If the item moves away from that position during normal operations, the voltage might increase considerably. In this case, further measurements shall be made with the item positioned away from the non-insulating surface.

19.5 Troubleshooting

- Verify that the test equipment is operating properly, check or service the battery (if battery operated), following the manufacturer's operating instructions for proper operation.

If a process essential insulator is found to have a field strength that exceeds the maximum requirement of the user ESD program, the risk may be ameliorated by one or more of the following options:

- replacement of the insulator with a suitable grounded conductor;
- reduction of the surface charge using an ionizer;
- treatment with a topical antistatic liquid;
- separation of the insulator from the ESDS by a minimum of 30 cm;
- another user specified method.

Avoid contacting the field meter sensing plates or the insulator under test with fingers, gloves or any object or materials. Any foreign residue or material on the meter's sensing plate might affect its ability to properly and accurately measure electric field strength.

20 Process essential isolated conductors

20.1 Basis of test procedure

The use of electrostatic voltmeters is referenced in the following publications:

- IEC TR 61340-1 [1];
- IEC TR 61340-5-2 [2].

20.2 Objective

The objective of this compliance verification test procedure is to verify that process essential isolated conductors do not exceed the maximum electrostatic field strength or surface potential allowed by the user's ESD control program.

When making measurements on process essential isolated conductors, it is important to take account of any charging mechanisms (contact and separation processes, rubbing, etc.) that might charge the conductors, and to replicate those processes as closely as possible before making measurements.

A conductor that could make contact with ESDS shall be grounded if possible. If it is not possible to ground an isolated conductor, prevent contact with ESDS, or remove it from the process, then the voltage on it shall be measured. It can then be compared with the voltage on any ESDS which it might contact to determine if the difference is within the user's specifications.

20.3 Test equipment

See Clause 6 for general description of test equipment.

- Electrostatic field meter calibrated as electrostatic voltmeter or electrostatic voltmeter (non-contacting or high-impedance contacting).

20.4 Test procedures

- Ground the meter (some meters can be grounded via a grounded person holding the case).
- Zero the meter in accordance with the manufacturer's instructions if required.
- Position the meter at the correct distance from the surface to be measured in accordance with the manufacturer's instructions.
- Allow the reading to stabilize and then record the reading.

Some isolated conductors can come into contact with charged objects during their process steps which can influence the level of surface voltage considerably. If the item moves to and away from that position during normal operations, the measurements should be made with the item in contact as well as positioned away from the isolated conductor surface.

20.5 Troubleshooting

- Verify that the test equipment is operating properly, check or service the battery (if battery operated), following the manufacturer's operating instructions for proper operation.
- If an isolated conductor that might come into contact with ESDS is found to acquire a potential that exceeds the maximum difference with the ESDS, risk can often be ameliorated by one or more of the following actions:
  - Ground or equipotentially bond the conductor.
  - Reduce the potential difference between the conductor and ESDS using an ionizer.
  - Apply another user specified measure.

Annex A
(informative)

Test frequency

The objective of the compliance verification test methods listed in this document is to identify if significant changes in ESD control equipment and materials performance have occurred over time.

Test frequency limits are not listed in this document, as each user will need to develop their own set of test frequencies based on the critical nature of those ESD sensitive items handled and the risk of failure for the ESD control equipment and materials.

Examples of how test frequencies are considered:

Daily wrist strap checks are sufficient in some applications while in other operations constant wrist strap monitoring can be used for added operator grounding reliability.

Packaging checks might depend on the composition of the packaging and its use. Some packaging might have static control properties that deteriorate more quickly with time and use, and some packaging might be humidity dependent and might have limited shelf life. Different items of packaging can look identical but have very different electrostatic properties. As there is a greater risk of confusion, it might be necessary to test samples of packaging more frequently.

Some materials, such as ESD floor finishes, might require more frequent monitoring because of their lack of permanency. Other materials, such as ESD vinyl floor covering or self-levelling floor systems, might require less monitoring. The testing of a floor should also be considered after maintenance on the floor has been performed.

Footwear check frequency should be based on the organization's experience.

Annex B
(informative)

Verification of compliance verification test equipment

B.1 General

Compliance verification test equipment is normally calibrated periodically as other test equipment. Annex B describes simple tests that can be used in the workplace to verify that it is working correctly.

All battery powered equipment should be checked for battery charge state before use. If there is doubt about their condition, batteries should be charged or replaced as appropriate.

It is advisable to check and note the ambient humidity in the work area before tests. High humidity can affect material properties and can lead to problems with some test equipment.

B.2 Charged plate monitor

B.2.1 Common problems

Common problems affecting charged plate monitors include

- inability to achieve the required plate voltage;
- drain of charge from the plate due to humidity or other unexpected current paths;
- presence of nearby conductors including the user's body leading to increased capacitance and increased decay times;
- nearby charged insulators (including the operator's clothing) that can induce voltages on the plate;
- air flow (e.g., drafts from fans or windows) that can affect measurements.

B.2.2 Basic charged plate monitor checks

The charged plate monitor should be initially checked as follows.

- Place the charged plate monitor in a suitable position for checking, away from conductors, charged insulators or ionizers.
- The plate should be charged to 1000 V or more and not degrade by 10 % after 1 min.
- Repeat this test for −1 000 V.

B.2.3 Visual checks in the position of measurement

Before measurements are made, the vicinity should be checked for charged insulators or conductors or air currents that could affect the results.

Check for differences in plate voltages that appear to be caused by the user approaching the instrument.

B.3 Electrodes

B.3.1 Common problems

Electrodes (concentric ring electrode assembly, resistance measurement electrode, two-point probe and surface resistance bar electrodes) are normally very reliable. Nevertheless, they can be subject to some problems.

- Electrode surfaces can become contaminated with dirt or chemicals.
- Planar electrodes can become warped over time.
- Integrated electrodes such as the concentric ring and two-point probe can suffer leakage due to insulation failure, contamination or high air humidity. If held in the hand, leakage through the user's body can occur.

B.3.2 Visual checks

Electrodes should be visually checked before use. If necessary, they can be cleaned with a suitable liquid cleaner in accordance with manufacturer's instructions. In the absence of other instructions, they can be wiped with iso-propyl alcohol (IPA) and left to dry thoroughly before use.

NOTE If not dry, the presence of cleaner might affect measurement results.

B.3.3 Electrode resistance test

An electrode set may be tested using a resistance measuring apparatus and a clean uncoated flat metal plate surface.

- Connect the resistance measuring apparatus to the electrodes under test.
- Place the electrodes on the metal plate.
- Measure the resistance through the electrodes.

The electrode resistance should be compared with the specification of the electrodes. For the electrodes specified in IEC 61340-2-3 the electrode resistance is expected to be less than $1{,}0 \times 10^3$ Ω when measured at (10,0 ± 0,5) V.

B.3.4 Electrode leakage test

An electrode set can be tested for leakage using a resistance measurement apparatus and insulative support.

- Connect the resistance measuring apparatus to the electrodes under test.
- Place the electrodes on the insulative support.
- Measure the resistance through the electrodes.

The resistance reading should indicate extremely high resistance at the limit of measurement with the equipment.

B.3.5 Electrode test with known resistance

If a sample of known material is available, this can be used as a system verification test for the electrodes in combination with the resistance measuring apparatus.

- Connect the electrodes to the resistance measuring apparatus.
- Place the electrodes on the sample material.
- Note the reading.

NOTE With some materials it might be necessary to place the material on an insulative surface before testing.

B.4 Resistance measuring apparatus

B.4.1 Common problems

The resistance measuring apparatus can give the following problems.

- The test voltage might drift from the required value, especially under load.
- A measurable high resistance might be indicated even when disconnected, due to leakage or high humidity levels. The leakage might be within test leads or within the meter.

B.4.2 Testing for leakage within the meter and leads

The resistance measuring apparatus and leads can be easily tested for internal leakage using an insulative surface.

- Disconnect the test leads from the meter.
- Turn on the meter and select the required test voltage.
- Note the resistance reading.

The resistance reading should indicate extremely high resistance at the limit of measurement with the equipment.

Connect the test leads, placing the leads on an insulative surface. Repeat the test above with leads connected. The resistance reading should indicate extremely high resistance at the limit of measurement with the equipment.

Repeat the above test with the test leads held in the user's hand. The resistance reading should indicate extremely high resistance at the limit of measurement with the equipment.

NOTE 1 If any of the above tests show readings below the upper limit of measurement, leakage is indicated.

NOTE 2 Effects similar to those seen with leakage can sometimes also be observed in the presence of high electromagnetic fields.

B.5 Insulative support surface

B.5.1 Common problems

An insulative surface might have insufficiently high surface resistance due to surface contamination or high atmospheric humidity.

B.5.2 Testing insulative surface resistance

An insulative surface can be tested using suitable electrodes as for ESD packaging. The resistance reading should indicate extremely high resistance at the limit of measurement with the equipment, or at least ten times greater than the resistance expected in the test in which it will be used.

If the resistance of the surface is lower than expected, it can be cleaned with a suitable cleaner. Iso-propyl alcohol, IPA, can be used to clean many materials. If a liquid cleaner is used, the material should be allowed to dry thoroughly before retesting.

B.6 Electrostatic field meter

B.6.1 Common problems

Electrostatic field meter readings can be affected by the presence of nearby conductors (including the user's body) and lack of proper grounding of the meter.

Field meters can be grounded though a separate ground wire. In many cases, they are designed to be adequately grounded when hand-held by a grounded user.

B.6.2 Visual and other pre-use checks

Before the field meter is used, check whether it is to be grounded through the user or via a separate ground cord. If the meter is grounded via the user, check that they are adequately grounded via a wrist strap or footwear and flooring at the place of measurement.

When in use, check whether the item to be measured is fixed or moveable. If fixed, it should be tested in its normal working position in the presence of any normal nearby conductors. If moveable, it might be necessary to move it away from any conductors that could influence measurements.

B.6.3 Checking field meter grounding

If the electrostatic field meter is grounded via a ground cord, the resistance between the connection point on the electrostatic field meter and the common ground point or ESD ground via the ground cord can be measured. If the measured resistance is outside the user's specified limits, the ground cord should be replaced and retested.

If the electrostatic field meter is grounded via the user's body, the resistance between the electrostatic field meter and the common ground point or ESD ground, either via the person and a wrist strap, or via the person, footwear and flooring can be measured. If the measured resistance is outside of the user's specified limits, separate resistance measurements can be made on the ground cord and footwear to determine which item(s) should be replaced.

B.6.4 Checking the electrostatic field meter operation

An electrostatic field meter can be checked in use by imposing a known voltage on an ungrounded, planar conductor and measuring that voltage.

Ideally, a metal plate should be used that is large enough to ensure a near uniform field in the region of the electrostatic field meter, which should be positioned near the centre of the plate. A square plate, for example, with side length at least four times the diameter of the electrostatic voltmeter sensing area is generally sufficient for compliance verification purposes.

A practical alternative conductor might be, for example, the planar side of a conductive tote box placed on an insulative support surface. The tote box should be homogeneously conductive so as to produce a near uniform field. The uniformity of the field can be checked by moving the electrostatic field meter over the surface of the conductor, without changing the separation distance, and observing any changes in the reading.

A resistance measuring apparatus can be used as a voltage source, if a dedicated DC voltage source is not available.

- Place the conductor on an insulative support.
- Connect the high voltage terminal of the DC voltage source to the conductor.
- Connect the other terminal of the DC voltage source to the ESD ground.
- Connect the voltmeter to be tested and hold it at the correct distance from the conductor surface, near the centre of the conductor.
- Apply the test voltage and note the reading.

B.7 Electrostatic voltmeter

B.7.1 Common problems

There are several types of electrostatic voltmeter. Readings can be affected by the presence of nearby conductors (including the user's body) and lack of proper grounding of the meter.

Electrostatic voltmeters can be grounded though a separate ground cord. In many cases, they are designed to be adequately grounded when hand-held by a grounded user.

Many common non-contact electrostatic voltmeters are field meters calibrated to read the voltage of a planar target at a known distance from the meter. The readings obtained with this type of instrument are influenced strongly by several factors including

- the size and shape of the target,
- the distance between the meter and the target,
- drift in the instrument.

With this type of electrostatic voltmeter, the surface voltage reading will be reduced if the target is smaller or further away than the calibration target. It will be increased if the target is larger or closer than the calibration target. The shape of the target might have an effect that is difficult to predict.

B.7.2 Visual and other pre-use checks

Before the voltmeter is used, check whether it is to be grounded through the user or via a separate ground cord. If the meter is grounded via the user, check that they are adequately grounded via a wrist strap or footwear and flooring at the place of measurement.

Some types of meter require zeroing in the absence of any electrostatic field before each measurement. This can often be done by the user covering the meter measurement aperture with their hand while zeroing the meter, provided the user is grounded or equipotentially bonded to the electrostatic voltmeter and the hand does not touch the sensing plate.

The user should check the calibration distance for the instrument before use. With practice, the meter can be held at the approximate calibration distance from the target with reasonable reliability.

B.7.3 Checking voltmeter grounding

If the electrostatic voltmeter is grounded via a ground cord, the resistance between the connection point on the electrostatic voltmeter and the common ground point or ESD ground via the ground cord can be measured. If the measured resistance is outside the user's specified limits, the ground cord should be replaced and retested.

If the electrostatic voltmeter is grounded via the user's body, the resistance between the electrostatic voltmeter and the common ground point or ESD ground, either via the person and a wrist strap, or via the person, footwear and flooring can be measured. If the measured resistance is outside of the user's specified limits, separate resistance measurements can be made on the ground cord and footwear to determine which item(s) should be replaced.

B.7.4 Checking voltmeter operation

An electrostatic voltmeter can be checked in use by imposing a known voltage on an ungrounded planar conductor and measuring that voltage.

Ideally, a metal plate should be used that is large enough to ensure a near uniform field in the region of the electrostatic voltmeter, which should be positioned near the centre of the plate. A

square plate, for example, with side length at least four times the diameter of the electrostatic voltmeter sensing area is generally sufficient for compliance verification purposes.

A practical alternative conductor might be, for example, the planar side of a conductive tote box placed on an insulative support surface. The tote box should be homogeneously conductive so as to produce a near uniform field. The uniformity of the field can be checked by moving the electrostatic voltmeter over the surface of the conductor, without changing the separation distance, and observing any changes in the reading.

A resistance measuring apparatus can be used as a voltage source, if a dedicated DC voltage source is not available.

- Place the conductor on an insulative support.
- Connect the high voltage terminal of the DC voltage source to the conductor.
- Connect the other terminal of the DC voltage source to the ESD ground.
- Connect the voltmeter to be tested and hold it at the correct distance from the conductor surface, near the centre of the conductor.
- Apply the test voltage and note the reading of the electrostatic voltmeter.

Annex C
(informative)

Other test methods for static control garments

C.1 General considerations for other test methods

Some static control garments contain materials that are not accessible for resistance measurements by the methods described in Clause 16 or Clause 17. Examples of such fabrics include those containing core-conductive fibres and some coated or laminated fabrics. Such garments cannot be used as groundable static control garments or in groundable static control garment systems, but they can still be used as part of an ESD control program.

In some cases, an organization might decide to use the test methods described in Clause 16 and/or Clause 17, but specify a higher range of resistance than that specified in IEC 61340-5-1. The acceptable resistance range should be documented in the user's ESD control program plan and compliance verification plan.

Compliance verification testing and acceptance limits for garments for which resistance measurements are not appropriate should be described in the user's ESD control program plan and compliance verification plan.

IEC TS 61340-4-2 [12] describes test methods for garments and garment materials, some of which are appropriate for compliance verification testing and are summarized in Annex C.

C.2 Precautions to be observed when conducting tests

The test procedures described in Annex C involve the use of reference materials that might acquire and retain charge, test equipment that generates electrostatic fields, and other procedures that are not normally permitted in an EPA when unprotected ESDS are present. Therefore, testing should be done outside an EPA, or within an EPA in which all ESDS have been removed or placed in ESD control packaging prior to the start of testing.

C.3 Tribocharging tests for garments

C.3.1 Objectives

The objective of these compliance verification test procedures is to determine if the net charge generated on garments after tribocharging is below the maximum value allowed by the user's specification.

Charge is measured directly, or is determined by measuring parameters that are proportional to charge: body voltage, electrostatic field or surface voltage.

C.3.2 Test equipment for body voltage measurements

See Clause 6 for general description of test equipment and Clause A.1, Clause B.1, C.2.2 and C.3.2 of IEC TS 61340-4-2:2013 [12].

- Electrostatic voltmeter capable of measuring body voltage of either polarity up to a voltage greater than the maximum voltage allowed by the user's specification.
- Reference rubbing materials: garments, seat covers or pieces of fabric as appropriate to the test procedure. These should be representative of the materials likely to contact the garments under test when in use, or that are known to generate high levels of charge on non-static control garments. Examples of suitable materials include polyamide, wool, leather, polyester, polyvinylchloride and polytetrafluoroethylene.

- Metal base plate for person to stand on. Body voltage measurements can be made with the person grounded as they would be in normal operations, in which case a base plate is not required. However, in order to distinguish between good and poor garments, it might be better to measure body voltage on an isolated person or with a resistance to ground somewhat higher than is normally specified for normal operations. In this latter case the metal base plate is placed on insulating support and can either be kept isolated during measurements or connected to ground via a resistor of specified value. The user's compliance verification plan should specify if body voltage measurements are made on isolated persons or with a specific resistance to ground.
- Seat (optional), as used in normal operations, or one kept specifically for compliance verification testing of garments.
- Mannequin (optional). The user's compliance verification plan should specify the design and electrical characteristics (surface resistance of covering, capacitance, etc.) of the mannequin.

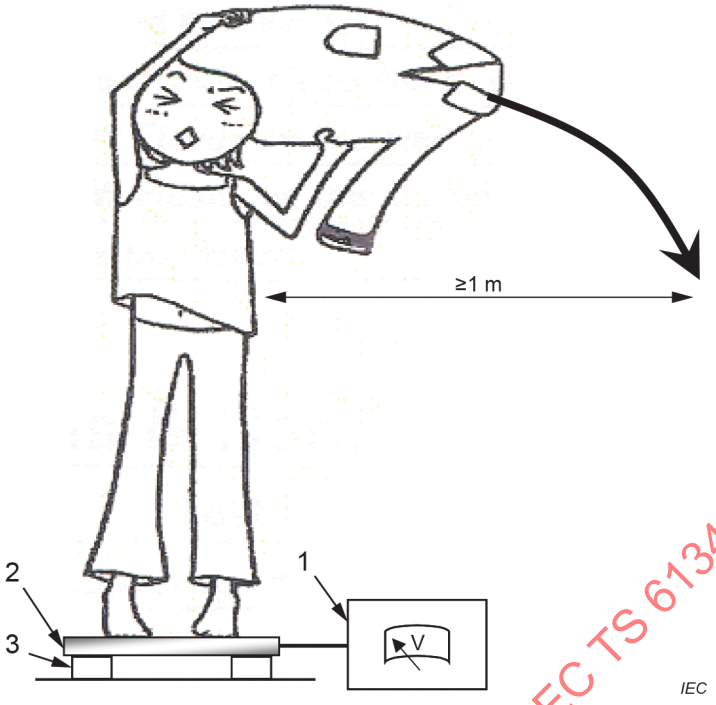
C.3.3 Test procedure for body voltage measurements

C.3.3.1 Testing by removal of garments

This test procedure is based on a similar procedure described in Clause A.2 and C.2.3 of IEC TS 61340-4-2:2013 [12].

- The test person puts on the garment under test, or it is placed on the mannequin.
- The reference garment is put on top of the garment under test.
- The test person stands on the metal base plate.
- Connect the electrostatic voltmeter to the metal base plate.
- Momentarily ground the test person or mannequin.
- Remove the reference garment and place it at least 1 m from the person under test or mannequin.
- Record the maximum body voltage.

An example of a suitable test set-up is shown in Figure C.1.



Key

1 electrostatic voltmeter
2 metal base plate
3 insulating support

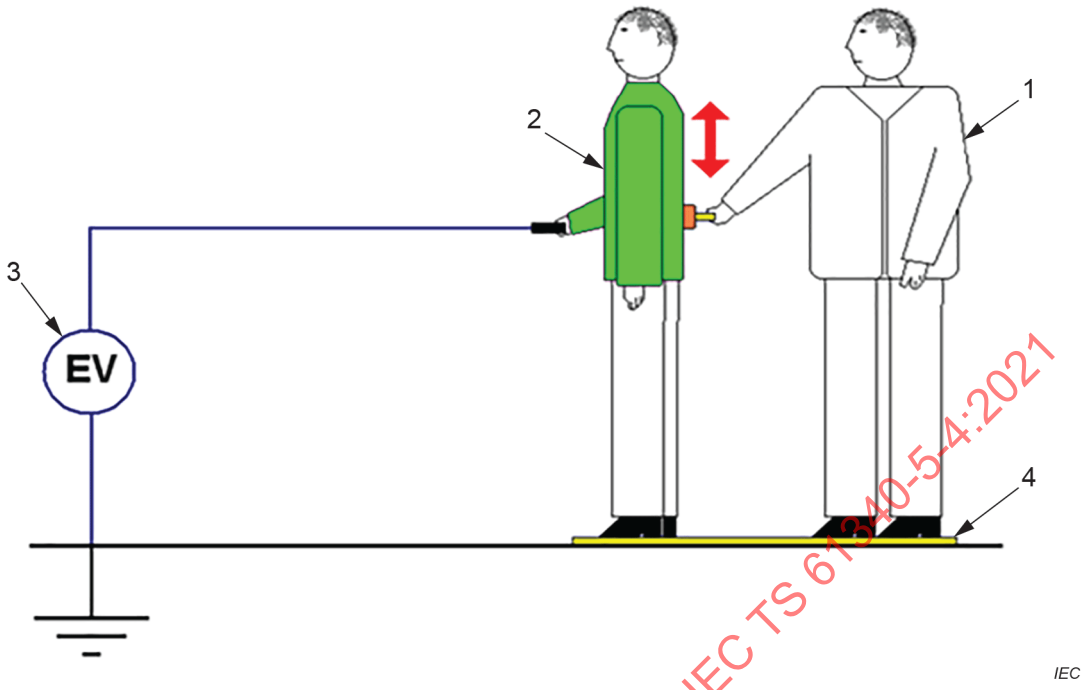
Figure C.1 – Example of a test set-up for measuring body voltage whilst removing a garment

C.3.3.2 Testing by rubbing a garment

This test procedure is based on a similar procedure described in C.3.3 of IEC TS 61340-4-2:2013 [12].

- The test person puts on the garment under test, or it is placed on the mannequin.
- The test person stands on the isolated metal base plate.
- Connect the test person or mannequin to the electrostatic voltmeter.
- Momentarily ground the test person or mannequin.
- Rub the garment under test with the reference material.
- Record the maximum body voltage.

An example of a suitable test set-up is shown in Figure C.2.



Key

1 operator
2 test person
3 electrostatic voltmeter
4 insulating support

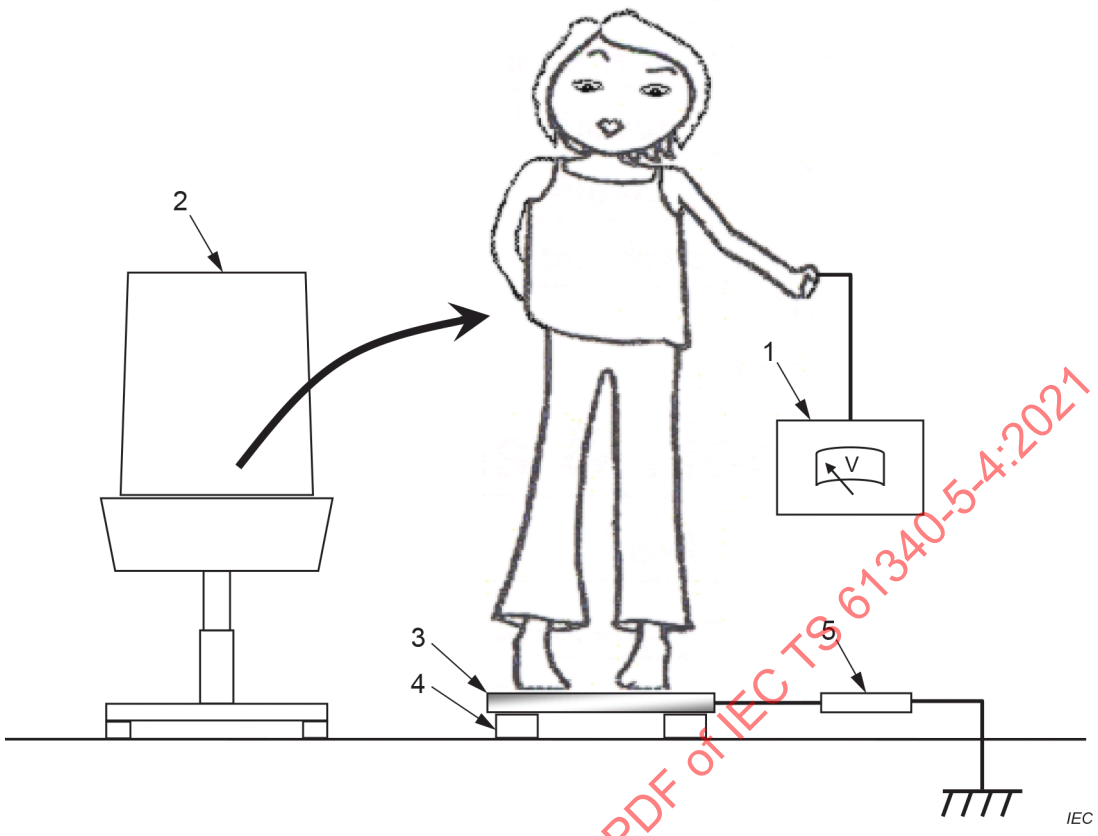
Figure C.2 – Example of a test set-up for measuring body voltage whilst rubbing the garment under test

C.3.3.3 Testing using a seat

This test procedure is based on a similar procedure described in Clause B.2 of IEC TS 61340-4-2:2013 [12].

- The test person puts on the garment under test.
- The test person sits down on the seat.
- Connect the test person to the electrostatic voltmeter.
- Momentarily ground the test person.
- The test person stands up onto the metal base plate.
- Record the maximum body voltage.

An example of a suitable test set-up is shown in Figure C.3.



Key

1 electrostatic voltmeter
2 seat
3 metal base plate
4 insulating support
5 resistor (optional)

Figure C.3 – Example of a test set-up for measuring body voltage on a person rising from a seat

C.3.4 Test equipment for measuring charge on garments

See Clause 6 for general description of test equipment, Clause A.1 and C.2.2 of IEC TS 61340-4-2:2013 [12], and 4.1.2 of IEC TR 61340-2-2:2000 [13].

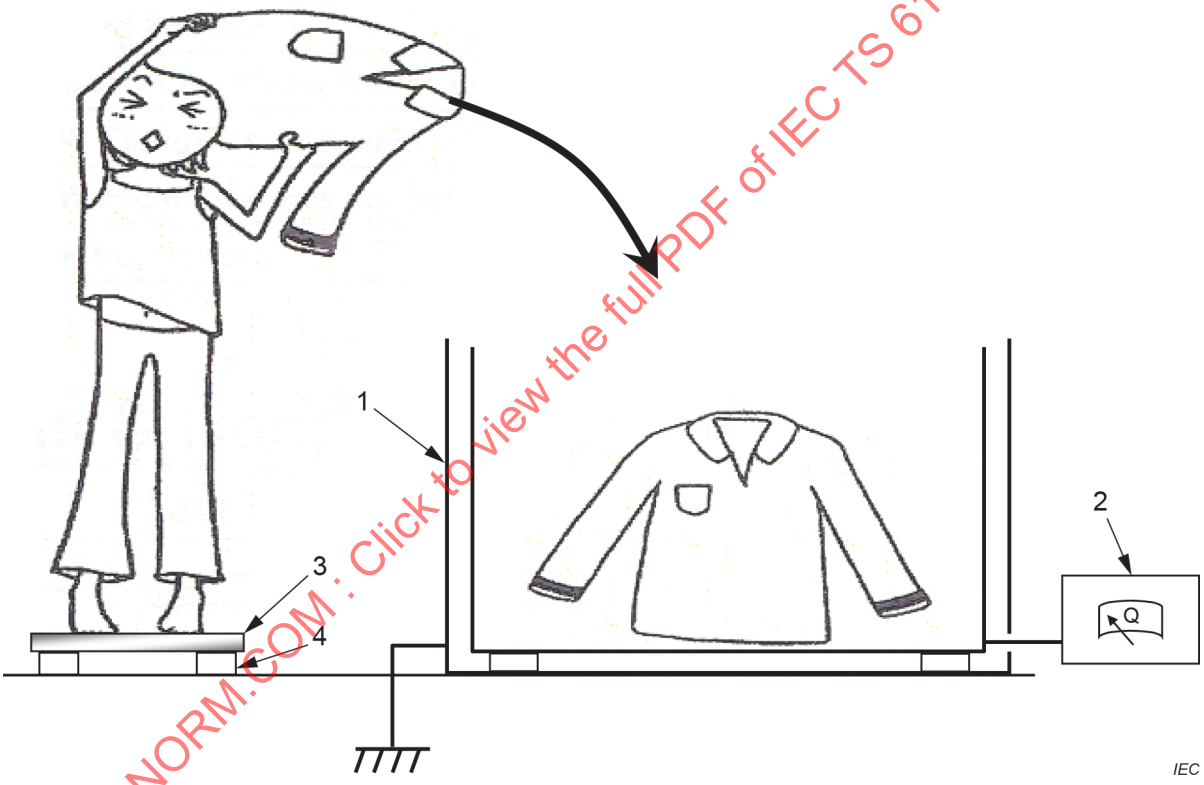
- Faraday pail capable of holding the entire garment under test.
- Charge measuring instrument. Electrostatic voltmeter, charge amplifier or coulombmeter to determine the charge induced on the inner container of the Faraday pail.
- Reference garments that are known to generate high levels of charge on non-static control garments. At least two reference materials should be used: one electropositive and one electronegative. Examples of suitable materials include polyamide, wool and polyester.
- Metal base plate for person to stand on. The metal base plate is placed on an insulating support and can either be kept isolated during measurements or connected to ground via a resistor of specified value. Measurements can also be made with the person grounded as they would be in normal operations, in which case a base plate is not required. The user's compliance verification plan should specify if measurements are made on isolated persons or with a specific resistance to ground.
- Mannequin (optional). The user's compliance verification plan should specify the design and electrical characteristics (surface resistance of covering, capacitance, etc.) of the mannequin.

C.3.5 Test procedure for measuring charge on garments

This test procedure is based on a similar procedure described in Clause A.2 and C.2.4 of IEC TS 61340-4-2:2013 [12].

- The test person puts on the garment under test, or it is placed on the mannequin.
- The garment under test is put on top of the reference garment.
- The test person stands on the metal base plate.
- Connect the Faraday pail to the measuring instrument.
- Momentarily ground the test person or mannequin, and the Faraday pail.
- Remove the garment under test and drop it into the Faraday pail.
- From the reading on the measuring instrument, determine the charge on the garment under test.

An example of a suitable test set-up is shown in Figure C.4.



Key

1 Faraday pail
2 charge measuring instrument
3 metal base plate
4 insulating support

Figure C.4 – Example of a test set-up for measuring charge on garments

C.3.6 Test equipment for measuring electrostatic field or surface voltage on garments

See Clause 6 for general description of test equipment and Clause E.1 of IEC TS 61340-4-2:2013 [12].

- Electrostatic field meter or non-contacting electrostatic voltmeter.

- Reference rubbing materials: objects (e.g. plastic pipes, blocks, balls) or pieces of fabric. These should be representative of the materials likely to contact the garments under test when in use, or that are known to generate high levels of charge on non-static control garments. In the latter case, at least two reference materials should be used: one electropositive and one electronegative. Examples of suitable materials include polyamide, wool, leather, polyester, polyvinylchloride and polytetrafluoroethylene.
- Metal base plate for person to stand on. The metal base plate is placed on an insulating support and can either be kept isolated during measurements or connected to ground via a resistor of specified value. Measurements can also be made with the person grounded as they would be in normal operations, in which case a base plate is not required. The user's compliance verification plan should specify if measurements are made on isolated persons or with a specific resistance to ground.

C.3.7 Test procedure for measuring electrostatic field or surface voltage on garments

This test procedure is based on a similar procedure described in Clause E.2 of IEC TS 61340-4-2:2013 [12].

- The test person puts on the garment under test.
- The test person stands on the metal base plate.
- Momentarily ground the test person.
- The test person makes a normal range of movements, for example bending, swinging arms, so that tribocharging occurs between different surfaces of the garments.
- Measure the electrostatic field or surface voltage at different locations about the body.
- Momentarily ground the test person.
- Rub the garment under test with the reference material.
- Measure the electrostatic field or surface voltage at different locations about the body.

C.3.8 Troubleshooting tribocharging tests

- Verify that the test equipment is operating properly and check or service the battery (if battery operated) following the manufacturer's operating instructions for proper operation.
- Ensure that measuring apertures in field meters and non-contacting voltmeters are clean and free of any obstructions.
- If results of measurements are significantly different to normal based on historical data, consider cleaning or changing reference rubbing materials.
- If results of measurements are still higher than normal, examine the garment, including seams and fastenings, to ensure it is not damaged or unduly soiled.
- Review laundry process:
  - high temperatures from washing, drying or ironing might damage coatings, topical finishes or conductive fibres in the garment;
  - some fabric softeners used in the laundry process can adversely affect electrostatic properties, for example by coating conductive fibres;
  - chlorine bleach can damage conductive fibres (especially silver based fibres);
  - some garments, typically from rental suppliers, require topical finishes or treatments to be re-applied after washing, either in the final rinse or as a separate process.

Defective static control garments that cannot be brought into compliance should be taken out of service and clearly marked as such.

C.4 Charge decay time tests for garments

C.4.1 Objective

The objective of these compliance verification test procedures is to determine if the rate at which electrostatic charge dissipates from garments is within the limits allowed by the user's specification.

Charge can be generated by tribocharging, by corona charging, or by direct connection to a DC high-voltage supply. Charge is not measured directly, but rather by measuring electrostatic field or surface voltage. Charge decay time is expressed as the time taken for the electrostatic field or surface voltage to fall from a defined initial value to a defined lower final value.

C.4.2 Test equipment for measuring charge decay time after tribocharging

Refer to Clause 6. For tests on garments as worn, an electrostatic field meter or non-contacting electrostatic voltmeter is used, with the addition of a means of recording time.

- Electrostatic field meter or non-contacting electrostatic voltmeter.
- Stopwatch or timer. Alternatively, the output from the electrostatic field meter or voltmeter can be recorded for subsequent analysis and determination of charge decay time.
- Reference rubbing materials: objects (e.g. plastic pipes, blocks, balls) or pieces of fabric. These should be chosen so as to generate sufficient charge on the garment under test such that the electrostatic field or surface voltage is greater than the initial value required for the test. Examples of suitable materials include polyamide, wool, leather, polyester, polyvinylchloride and polytetrafluoroethylene.
- Garment support surface, which may be insulating, dissipative or conductive. The user's compliance verification plan should specify the surface resistivity or resistance to ground of the garment support surface.

C.4.3 Test procedure for measuring charge decay time after tribocharging

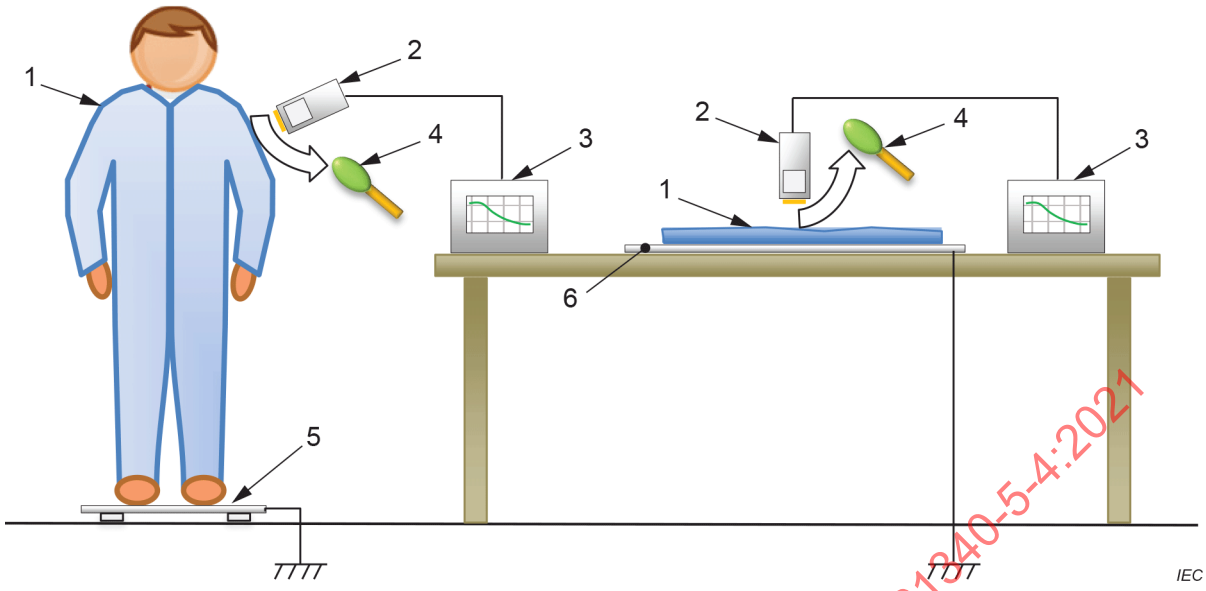
For tests on garments as worn, use the following procedure:

- The test person puts on the garment under test.
- The test person stands on the metal base plate.
- Momentarily ground the test person.
- Position the electrostatic field meter or non-contacting electrostatic voltmeter above the area to be charged.
- Rub the garment under test with the reference material.
- Record the time taken for the electrostatic field or surface voltage to fall from the initial value to the final value.

For bench-top tests on garments, use the following procedure:

- Place the garment under test on the garment support surface so that it touches nothing else.
- If necessary connect the garment to ground. Testing with or without a ground connection, and the means of grounding if required should be specified in the user's compliance verification plan.
- Position the electrostatic field meter or non-contacting electrostatic voltmeter above the area to be charged.
- Rub the garment under test with the reference material.
- Record the time taken for the electrostatic field or surface voltage to fall from the initial value to the final value.

Examples of suitable test set-ups are shown in Figure C.5.



Key

1 garment under test
2 electrostatic field meter or non-contacting electrostatic voltmeter
3 data recorder
4 rubbing material
5 metal base plate
6 garment support surface

Figure C.5 – Examples of test set-ups for measuring charge decay time on garments as worn and on a bench-top after tribocharging

C.4.4 Test equipment for measuring charge decay time after corona charging

See Clause 6 for general description of test equipment. The equipment used is the same as specified in C.4.3, except the rubbing material is replaced by a corona array and DC high-voltage supply. The corona array consists of fine conductive points or wires. The configuration of the corona array and the voltage to which it is energized should be specified in the user's compliance verification plan. Alternatively, for bench-top tests on garments, the test equipment specified in IEC 61340-2-1 [14] can be used.

C.4.5 Test procedure for measuring charge decay time after corona charging

For tests on garments as worn, use the following procedure:

- The test person puts on the garment under test.
- The test person stands on the metal base plate.
- Momentarily ground the test person.
- Position the electrostatic field meter or non-contacting electrostatic voltmeter above the area to be charged.
- Energize the corona array and pass it over the garment under test without the corona array touching the garment.
- Move the corona array at least one metre away from the garment under test and switch it off.
- Record the time taken for the electrostatic field or surface voltage to fall from the initial value to the final value.

For bench-top tests, use the procedure specified in IEC 61340-2-1 [14], or the following procedure:

- Place the garment under test on the garment support surface so that it touches nothing else.
- If necessary, connect the garment to ground. Testing with or without a ground connection, and the means of grounding if required should be specified in the user's compliance verification plan.
- Position the electrostatic field meter or non-contacting electrostatic voltmeter above the area to be charged.
- Energize the corona array and pass it over the garment under test without the corona array touching the garment.
- Move the corona array at least one metre away from the garment under test and switch it off.
- Record the time taken for the electrostatic field or surface voltage to fall from the initial value to the final value.

C.4.6 Test equipment for measuring charge decay time after connection to a DC high-voltage supply

Refer to Clause 6 of this document and 6.3.4 of IEC TS 61340-4-2:2013.

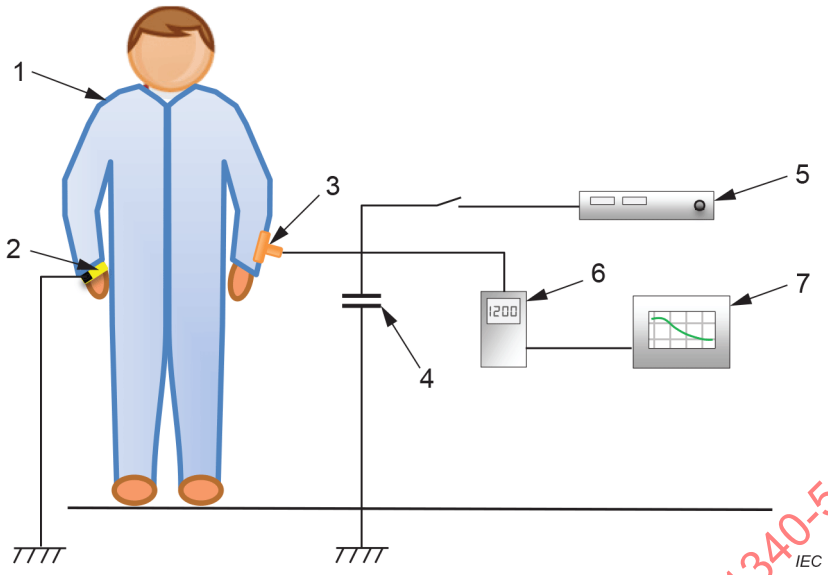
- charged plate monitor, or combination of DC high-voltage supply, electrostatic voltmeter and timer or recorder;
- 1 nF capacitor (rated to at least 600 V DC);
- wrist strap or footwear-flooring combination to ground person as in normal operations;
- insulating base plate (optional);
- garment contact clamp.

C.4.7 Test procedure for measuring charge decay time after connection to a DC high-voltage supply

This test procedure is based on a similar procedure described in 6.3.4 of IEC TS 61340-4-2:2013.

- The test person puts on the garment under test.
- The test person is grounded as in normal operations. The test person can wear a wrist strap connected to ground whilst standing on the insulating base plate, can be grounded via a footwear-flooring combination, or can be grounded via a wrist strap and by a footwear-flooring combination. The protocol used for grounding should be specified in the user's compliance verification plan.
- The capacitor is charged to a convenient value above the initial value. If a DC high-voltage supply is used, disconnect it after charging the capacitor.
- Discharge the capacitor by connecting it to the garment under test via the garment contact clamp.
- Record the time taken for the voltage on the capacitor to fall from the initial value to the final value.

An example of a suitable test set-up is shown in Figure C.6.



Key

1 garment under test
2 wrist straps
3 garment contact clamps
4 capacitors
5 DC high-voltage supply
6 electrostatic voltmeters
7 data recorders

Figure C.6 – Example of test set-up for measuring charge decay time after connecting a garment to a DC high-voltage supply

C.5 Field suppression tests for garments

Refer to 6.5 of IEC TS 61340-4-2:2013 [12].

C.6 Capacitance loading tests for garments

Refer to 6.8 and Annex D of IEC TS 61340-4-2:2013 [12].