IEC TR 61340-5-2

Edition 2.0 2018-03

TECHNICAL REPORT

colour inside

Electrostatics –
Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide

IEC TR 61340-5-2:2018-03(en)

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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.
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IEC TR 61340-5-2, which is a Technical Report, has been prepared by IEC technical committee 101: Electrostatics.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

This second edition of IEC TR 61340-5-2 has been modified to provide guidance for users of IEC 61340-5-1:2016. The text has been arranged to follow the requirements of

IEC 61340-5-1:2016 as closely as possible as well as providing specific guidance on each of the requirements of IEC 61340-5-1:2016.

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

Enquiry draft	Report on voting
101/532/DTR	101/543/RVDTR

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 "http://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.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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

This user guide has been produced for individuals and organizations that are faced with controlling electrostatic discharge (ESD). It provides guidance that can be used for developing, implementing and monitoring an electrostatic discharge control program in accordance with IEC 61340-5-1.

This user guide applies to activities that manufacture, process, assemble, install, package, label, service, test, inspect or otherwise handle electrical or electronic parts, assemblies and equipment susceptible to damage by electrostatic discharges greater than or equal to 100 V using the human body model (HBM), 200 V charged device model (CDM) or 35 V on isolated conductors. Isolated conductors were historically represented by the machine model (MM). The MM test is no longer used for qualification of devices, only HBM and CDM. The MM is retained in this document for process control of isolated conductors. These three levels were selected for IEC 61340-5-1 as the baseline susceptibility threshold, since a large majority of the ESD products on the market have a sensitivity of greater than 100 V HBM, 200 V CDM and 35 V for isolated conductors. If ESD sensitive devices (ESDS) of less than these values are being handled, additional controls can be implemented or some of the technical control item requirements can be adjusted.

The requirements established for each of the ESD control items are specified for an ESD control program designed for 100 V HBM, 200 V CDM and 35 V for isolated conductors. The 100 V HBM value is predicated on maximum voltage levels attainable on an individual when they are grounded via techniques accepted throughout the electronics industry as outlined in IEC 61340-5-1.

For organizations concerned with charged device model damage, IEC 61340-5-1 establishes requirements concerning the use of insulators in the ESD protected area (EPA) based on maximum electrostatic field limits.

Any contact and physical separation of materials or flow of solids, liquids, or particle-laden gases can generate electrostatic charges. Common sources of ESD include charged: personnel, conductors, common polymeric materials, and processing equipment. ESD damage can occur when:

- a charged person or object comes into contact with an ESDS;
- an ESDS comes into direct contact with a highly conductive surface while exposed to an electrostatic field;
- a charged ESDS comes into contact with another conductive surface which is at a different electrical potential. This surface may or may not be grounded.

Examples of ESDS are microcircuits, discrete semiconductors, thick and thin film resistors, hybrid devices, printed circuit boards and piezoelectric crystals. It is possible to determine device and item susceptibility by exposing the device to simulated ESD events. The level of sensitivity, determined by test using simulated ESD events, may not necessarily relate to the level of sensitivity in a real life situation. However, the levels of sensitivity are used to establish a baseline of susceptibility data for comparison of devices with equivalent part numbers from different manufacturers. Three different models have been used for qualification of electronic components – human body model (HBM), machine model (MM), and charged device model (CDM). In current practice, devices are qualified only using HBM and CDM susceptibility tests.

The general principles described in IEC 61340-5-1 are not limited in their applicability to ESDS with ESD sensitivities defined in IEC 61340-5-1 (e.g. 100 V HBM). For organizations that handle ESDS with withstand voltages higher or lower than those defined in IEC 61340-5-1, the general principles of IEC 61340-5-1 can still be used. The organization can modify some of the required limits specified in Tables 2 to 3 of IEC 61340-5-1:2016. The program documentation identifies the lowest ESDS withstand voltage(s) that can be handled, and if different to those defined in IEC 61340-5-1, appropriate changes to the limits specified in IEC 61340-5-1 can be made in the program documentation.

The fundamental ESD control principles that form the basis of IEC 61340-5-1 are as follows:

a) Avoid a discharge from any charged, conductive object (personnel, equipment) into the sensitive device:

   It is preferred that all conductors that may come into contact with ESDS including personnel, are bonded or electrically connected to a known ground or contrived ground (as on shipboard or on aircraft). This attachment creates an equipotential balance between all items and personnel. Electrostatic protection can be maintained at a potential different from “zero” voltage ground potential, as long as all items in the system are at the same potential. If a conductor that cannot be grounded (e.g. isolated conductor) comes into contact with an ESDS, the ESD risk should be evaluated and if necessary mitigated.

b) Avoid a discharge from any charged ESD sensitive device (the charging process that can lead to a discharge can result from direct contact and separation or can be field induced):

   Insulators cannot lose their electrostatic charge by grounding. It is preferred that insulators should be removed from the vicinity of ESDS. Some insulators are essential to the process or product and cannot be removed from the vicinity of the ESDS. Ionization or other mitigating techniques can provide neutralization of charges on these essential insulators (circuit board materials and some device packages are examples of essential insulators). Assessment of the ESD hazard created by electrostatic charges on the essential insulators in the work place is done to ensure that appropriate actions are implemented, according to the risk.

c) Once outside of an electrostatic discharge protected area (hereafter referred to as an EPA) it is generally not possible to control the above items, therefore, ESD protective packaging can be used. ESD protection can be achieved by enclosing ESD sensitive products in static protective materials, although the type of material depends on the situation and destination. Inside an EPA, static dissipative materials may provide adequate protection. Outside an EPA, low charging and static discharge shielding materials are recommended. While all of these materials are not discussed in this document, it is important to recognize the differences in their application. Requirements and associated test methods for ESD protective packaging are specified in IEC 61340-5-3.

Each organization has different processes, and so there will be a different blend of ESD prevention measures for an optimum ESD control program. It is vital that these measures are selected, based on technical necessity and carefully documented in an ESD control program plan, so that all concerned can be sure of the program requirements.

Training is an essential part of an ESD control program in order to ensure that the personnel involved understand the equipment and procedures they are to use in order to be in compliance with the ESD control program plan. Training is also essential in raising awareness and understanding of ESD issues. Without training, personnel are often a major source of ESD risk. With training, they become an effective first line of defence against ESD damage.

Regular compliance verification checks and tests are essential to ensure that equipment remains effective and that the ESD control program is correctly implemented in compliance with the ESD control program plan.

ELECTROSTATICS –

Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide

1 Scope

This part of IEC 61340, which has been developed to support IEC 61340-5-1, applies to activities that: manufacture, process, assemble, install, package, label, service, test, inspect, transport or otherwise handle electrical or electronic parts, assemblies and equipment with withstand voltages greater than or equal to 100 V HBM, 200 V CDM and 35 V for isolated conductors. Additional control elements or adjusted limits can be applicable for ESDS with lower withstand voltages.

NOTE Isolated conductors were historically represented by MM.

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 61340-5-1:2016, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61340-5-1 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

3.2 Abbreviated terms

AHE automated handling equipment

CDM charged device model

CPM charged plate monitor

DUT device under test

EPA ESD protected area

ESD electrostatic discharge

ESDS ESD sensitive device

HBM human body model

MM machine model

MVTR moisture vapour transmission rate

PPE personal protective equipment

RC resistor-capacitor

4 Personnel safety

The procedures and equipment described in this document may 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 cannot replace or supersede any requirements for personnel safety.

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

5 ESD control program

5.1 General

5.1.1 ESD control program requirements

The program includes both administrative and technical requirements as described in IEC 61340-5-1, which requires the organization to establish, document, implement, maintain and verify the compliance of the program.

5.1.2 ESD coordinator

An ESD coordinator is a person appointed by the organization to be responsible for organizing and maintaining the ESD control program. In order to have a well thought out and implemented ESD control program, IEC 61340-5-1 requires that an ESD coordinator be assigned. The ESD coordinator is responsible for all aspects of ESD in the facility. In order to be effective the ESD coordinator needs:

a) the full support of management;

b) a good understanding of electrostatics and how ESD sensitive devices can be damaged; the ESD coordinator will often need to attend educational classes or seminars related to ESD in order to maintain or update knowledge;

c) a thorough understanding of IEC 61340-5-1 and all of the organization's processes related to the handling of ESD sensitive devices.

d) access to measuring equipment for the purposes of performing compliance verification measurements as well as testing new ESD products and materials for use in the ESD control program;

e) depending on the size of the facility, the ESD coordinator might also need to have auditors assigned to conduct the ESD audits.

Finally, management should provide the ESD coordinator with the authority and funding necessary to ensure that the ESD control program is maintained and enforced.

5.1.3 Tailoring

It is possible that portions of IEC 61340-5-1 may not apply to all areas within an organization. In these situations it is acceptable for the organization to document an exception to one or more of the required elements of IEC 61340-5-1 as long as there is a valid, substantiated and documented justification for the exception. An example of an acceptable exception to IEC 61340-5-1 can be found in the sample ESD control program plan at the end of this document (Annex A).

5.2 ESD control program administrative requirements

5.2.1 ESD control program plan

5.2.1.1 General

This clause outlines a step-by-step approach that can be used to establish an ESD control program.

5.2.1.2 Determination of ESD withstand voltage

One step in developing an ESD control program plan is to determine the part, assembly or equipment sensitivity level under which the plan is to be developed. Although the requirements outlined in IEC 61340-5-1 are effective for handling parts sensitive to 100 V HBM or 200 V CDM or higher, the organization may choose to develop an ESD control program based on ESD sensitivities that are greater or less than these limits. In this situation, the organization should develop an ESD control program plan that clearly states the ESD sensitivity that the program is based on.

The organization can use various methods to determine the ESD sensitivity of the products that are to be handled. Any of the following methods may be used:

- assumption that all ESDS products have an HBM withstand voltage of 100 V and 200 V CDM;
- actual testing of ESD sensitive devices to establish the ESD withstand voltage using IEC standards (see Bibliography);
- referencing ESD withstand voltage data in published documents such as manufacturer's published data sheets.

For more information see the Industry Council on ESD target levels white papers (www.esdindustrycouncil.org).

5.2.1.3 Initial process and organizational assessment

Before the ESD control program plan can be developed, an initial assessment of the processes and organizations impacted by an ESD control program should be conducted. Organizations and processes that might be affected include (this list represents examples of areas involved):

- purchasing (purchasing the qualified ESD control items);
- design engineering (selecting components/materials with consideration of ESD issues);
- receiving and inspection (taking care of handling ESD susceptible components as well as secondary packaging);
- quality assurance;
- manufacturing (design and operation of manufacturing lines);
- testing;
- maintenance (production/grounding);
- packaging and shipping;
- field service (implement ESD control during field service operations);
- failure analysis;
- repair services;
- spare parts storage;
- material handling and parts conveyance;
- facility management (e.g. cleaning/grounding).

An assessment of each area where ESDS parts are handled should be conducted in order to determine ESD hazards and the appropriate ESD control process procedures. The information accumulated throughout these steps forms the basis for developing the ESD control program plan.

5.2.1.4 Guidance of how to determine ESD hazards

The first step in determining ESD hazards is to identify whether ESD susceptible components, PCBs or other items (ESDS) are handled in the facility. Most semiconductors and some passive devices are ESDS. In general populated PCBs, modules and similar assemblies should be considered ESD susceptible. If their ESD withstand voltage is not known then assume the product is ESD sensitive. Even PCBs or modules that are fully contained within an enclosure may have some susceptibility to ESD that may enter via a connector or flying leads.

The second step is to identify the processes in which ESDS should be handled in an unprotected state. These processes may be manual or automated. A major contribution to ESD protection may be made by minimizing handling of ESDS in an unprotected state. Where handling is necessary, some form of ESD control is required – these are defined as ESD protected areas (EPA) in IEC 61340-5-1. All areas in which ESD controls are not applied are unprotected areas. Any ESDS in unprotected areas should be protected within ESD protective packaging of some form.

The third step is to identify the potential ESD sources in each process. The most common of these are;

- a charged person touching the ESDS;
- a charged metal or conductive object, tool or other item touching the ESDS;
- the ESDS becoming charged and touching a conductive item (e.g. metal part or equipment).

Electrostatic fields are not usually in themselves damaging (with a few exceptions). However electrostatic fields help set up the conditions in which ESD can occur because any isolated conductor (e.g. metal parts or the device itself) within the electrostatic field will attain a voltage. If two conductors touch (or become sufficiently close to each other) within an electrostatic field, and at least one is isolated, then ESD will probably occur between them.

A particularly damaging form of ESD can occur when an ESDS comes into contact with a high conductivity (low resistance, e.g. metal) item. An ESD event occurring in this circumstance can have a very short duration high discharge current. The susceptibility of the ESDS to this type of event is characterized by its charged device model (CDM) withstand voltage. This type of damage can often be avoided where the device instead makes contact with a higher resistance ($> 10^4\ \Omega$) resistance material.

5.2.1.5 How to determine appropriate ESD measures

It follows that the first step in determining the appropriate ESD control measures is to define the boundary of each EPA. These should then be marked or signed so that personnel can easily identify which areas are EPA and which are unprotected areas. Within the EPAs the ESD control measures can then be determined.

- Personnel handling ESDS are grounded so that they cannot be at a high enough voltage to damage the ESDS that they touch. This normally means that the body voltage on personnel should be reduced to less than the human body model withstand voltage of the ESDS.
- Any metal or conductive items, that make contact with ESDS, are grounded to ensure that they are not charged.

- Sources of high electrostatic fields (e.g. charged insulators or equipment that generates external electrostatic fields) are kept far enough away from ESDS not to risk inducing high voltages on the device.
- ESDS are often in an ungrounded state when they make contact with other components or process items; this can create charged device ESD risk. This risk should be managed by use of dissipative materials or reducing voltage differences.

5.2.1.6 Documentation of ESD control program plan

After gathering the above information, the organization is in a position to begin documenting the ESD control program plan. The plan should state the scope of the program which includes the tasks, activities and procedures necessary to protect the ESD sensitive items at or above the ESD sensitivity level chosen for the plan. Although the primary focus of the plan is to outline strategies for meeting the administrative and technical elements of IEC 61340-5-1, other items may be beneficial to incorporate as well. These additional items might include:

- organizational responsibilities;
- defined roles and responsibilities between the organization and subcontractors and suppliers;
- strategies for monitoring product yields and processes that might be important in determining the effectiveness of ESD control measures currently in place or in assessing whether additional measures should be taken;
- approaches for ensuring continual improvement of the ESD control program;
- a list of approved ESD control products and materials.

The administrative and technical elements of IEC 61340-5-1 that need to be addressed in the plan include:

- training plan;
- product qualification;
- compliance verification plan;
- grounding/bonding systems;
- personnel grounding;
- protected areas;
- packaging;
- marking.

5.2.2 Training plan

Training of personnel is a critical element in the implementation of an ESD control program. A sustained commitment and attitude among all personnel that ESD prevention is a valuable, continuing effort by everyone is one of the primary goals of training.

One of the first decisions that is to be made is who will be required to attend ESD training courses. IEC 61340-5-1 requires that, at a minimum, initial and recurrent ESD training be provided to all personnel that handle or otherwise come into contact with ESD sensitive items. This decision seems straight-forward but care should be taken to ensure that all people that handle ESD sensitive devices receive adequate training. One example is the finance department. Many people will immediately state that this group should be exempt from ESD training. However, in some organizations the finance department personnel are involved in the annual physical inventory where parts are counted. In these situations, the finance employees are touching ESD sensitive parts and therefore should receive ESD training in order for the organization to be in compliance with IEC 61340-5-1.

Although it is not a requirement of IEC 61340-5-1, the organization should consider providing some form of ESD training to personnel who do not handle ESD sensitive parts such as:

- managers, who may need to understand the implications of, and necessity for ESD prevention;
- cleaning and maintenance personnel who may need to work within the EPA; and
- purchasing personnel responsible for buying ESD susceptible parts and ESD control equipment.

For visitors to the EPA, the person escorting the visitor is responsible for ensuring that they are wearing the ESD control equipment required by the organization and that they understand what they may and may not do within the EPA.

Although personnel training can take several forms (i.e. instructor, computer based, etc.), the preferred technique for initial training is through the use of an instructor. Special care should be exercised in finding a "suitable" instructor. The instructor should have a good understanding of ESD theory and the organization's ESD control program and the processes, procedures and materials prescribed within. In addition, if manufacturing spans more than one culture, careful consideration should be given to customs and religious beliefs. Besides cultural differences, other factors such as education, experience and age should be considered. All training should be carried out in a secure, non-threatening environment.

One of the first steps is to determine the type(s) of ESD training methods that will work best for the organization. Some possible training methods include:

- in-house, instructor-led ESD class;
- in-house, consultant-led class;
- computer based training;
- industry symposia, tutorials and workshops;
- on the job training.

The initial training program should cover the fundamentals of ESD, the details of the organization's ESD control program plan, and each person's role in the ESD control program. The training program should answer the following basic questions:

- what is static electricity?
- how does it occur?
- how does ESD affect product quality?

A careful explanation of the protection process as part of organizations policy should be included. No matter which type of training method is chosen, the program should be designed so that all trainee questions that arise can be answered. In addition, a knowledgeable person in the organization should be available to answer trainee questions once they have begun working. Opening the lines of communication is the beginning of a successful ESD training program. This type of communication should continue in the workplace and form the basis for an ongoing education process. It is a requirement in IEC 61340-5-1 that initial ESD training is provided before personnel handle ESD sensitive devices.

Because ESD control programs cover such a variety of job disciplines and educational levels, it may be necessary to develop special job specific training modules. Advanced modules should emphasize the main concerns of each discipline. Course emphasis should be tailored to each group's specific needs. For example, the modules developed for management, engineering, technicians, cleaning staff and field service could differ significantly because their day-to-day concerns and responsibilities are much different.

Ongoing or refresher training is also vital to any organization's training plan. It should reinforce the basic fundamentals taught during initial training, but also should incorporate program updates and changes and the reasons for those changes. As with the initial training, the organization should decide which type of training will be used and how frequently the recurring training will be required. The method chosen should keep everyone informed, renewing his or her commitment to the total ESD control effort. Recurring training is also a good feedback loop for monitoring the program's effectiveness. Personnel should be encouraged to discuss issues, and make suggestions for improvement in these sessions. Actions can then be assigned to improve the organization's overall ESD control program.

After training (initial or recurring) sessions have been completed, it is important to ensure that the trainee understands and has retained the ESD control program concepts taught during these sessions. IEC 61340-5-1 requires that an objective evaluation technique be incorporated as part of the training plan. This can be accomplished in a number of ways that include written tests, question and answer sessions with an instructor or multiple choice questions at the conclusion of a computer based training session. Regardless of the method selected, the organization should establish a pass/fail criterion for the testing to ensure adequate training has been accomplished. Records of all test results should be maintained. The test records should be stored such that they are readily available to management and customers who want objective evidence that the training portion of the ESD control program plan is being adhered to.

Finally, since IEC 61340-5-1 requires recurring or "refresher" training, a system should be established to highlight when employees are due for retesting and/or recertification.

A repository or central information source of educational ESD control materials should be kept for reference at any time by organization employees. This repository might include:

- material from initial and recurring training sessions;
- ESD bulletins or newsletters;
- videos or CDs;
- computer-based training materials;
- technical papers, studies, standards and specifications;
- ESD control material and equipment product sheets.

5.2.3 Product qualification

It is of great importance for the organization that new ESD control items have the required properties before being allowed into the EPA.

Subclause 5.2.3 will discuss different ways of handling the product qualification procedure of ESD control items that the organization is required to undertake.

The product qualification requirements of the ESD control items are all present in IEC 61340-5-1 and IEC 61340-5-3 with the appropriate references to the test methods; however a tailoring statement might be present in the ESD control program plan that changes acceptance levels or test methods, as well as adding or subtracting ESD control items to the list. If an ESD control item is added to the list, an appropriate test method and acceptance limit should be stated in the ESD control program plan.

The main part of the information regarding the test methods and acceptance limits can be found in IEC 61340-5-1:2016, Table 2 and Table 3.

There are four different acceptable evidences of product qualification:

a) Product data sheets published by the manufacturer of the ESD control item
   1) should include a reference to the required test method, and
   2) should include the test result and other vital information concerning general requirements of IEC 61340-5-1 or IEC 61340-5-3.

b) Test reports from an independent test laboratory. The test report should follow the requirements of the test method as well as the general requirements of IEC 61340-5-1 or IEC 61340-5-3.

c) Test reports generated internally by the organization for its own use. The test report should follow the requirements of the test method as well as the general requirements of IEC 61340-5-1 or IEC 61340-5-3.

d) Historical evidence of compliance verification data can be used for product qualification. A general recommendation is that it should contain at least three years of data.

5.2.4 Compliance verification plan

5.2.4.1 General

A compliance verification plan (ensuring that the ESD control items are still functional) is an essential part of any ESD control program. While the compliance verification may occur on a periodic basis, it is considered part of the overall program. However it should not be considered an audit or assessment of the process.

NOTE An assessment or audit of the process is used to confirm that the ESD control program complies with all the requirements in IEC 61340-5-1. This is typically done in accordance with a quality management system with either internal or external assessors. If desired, third party external assessment could lead to certification that the ESD control process complies with IEC 61340-5-1. This type of assessment not only reviews the technical elements defined, but ensures that all administrative elements, such as product qualification and training, meet all the requirements.

5.2.4.2 Development of a compliance verification plan

Subclause 5.2.4.2 will discuss the importance of having a properly implemented compliance verification plan and its role in maintaining a successful ESD control program.

In order for the ESD control program to be successful it is essential to develop a plan for on-going surveillance. The plan should identify:

- the ESD control items that will be used,
- how often the item will be checked to ensure that it meets specification,
- the acceptable limits for each ESD control item used,
- the test methods that will be used to verify that each ESD control item is within established parameters,
- the equipment that will be used to check the various ESD control items,
- who will make the measurements,
- what will be done if an out of compliance situation occurs.

Compliance verification should be done after an ESD control item is installed and before it is used.

5.2.4.3 ESD control items

There are many ways to establish an ESD control program. A program can range from a very simple, low cost or basic system to an extensive system that uses a variety of control items that provide redundancy in the event that the primary ESD control element(s) were to fail.

A basic ESD control program might include the following items:

a) a grounded work surface;

b) personnel grounded through a wrist strap system;

c) ESD protective packaging to move ESDS from one process step to the next.

An extensive ESD control program might include the following items:

1) grounded work surfaces;
2) personnel grounded through constant wrist strap monitor;
3) personnel grounded to a ESD control floor through ESD control footwear;
4) personnel wearing grounded ESD control garments;
5) air ionization at each workstation.

The decision on what to include in an ESD control program is a matter of organization choice. Some of the considerations are: value of the products being manufactured, product reliability requirements imposed by the customer and the ESD sensitivity of the devices being handled. One type of program is not necessarily any better than the other as each can be effective in protecting ESD sensitive devices.

Once the ESD control items have been defined and implemented, the organization needs to develop a compliance verification plan. In order to establish meaningful data concerning improving or deteriorating ESD control program trends, it is necessary to evaluate each area consistently every time. Many organizations find that properly designed compliance verification plan helps improve consistency.

5.2.4.4 Verification frequency

The frequency for checking the function of ESD control elements is dependent on a number of factors such as how often the item is used, the item's durability and the impact on the ESD control program if the control item were to fail. As an example, wrist straps are often used as the primary ground for personnel. A ground cord, whilst being worn, is subjected to thousands of stretch/bend cycles each day and the conductive wire(s) in the ground cord will eventually break. The typical verification frequency, used by industry, for ground cords is once per shift due to the ground cord's importance to the success of the program and the likelihood of failure.

Some organizations may want to increase the time between verifications of an ESD control item after it has been in use for a period of time. This is typically done by monitoring the failures of the ESD control item. Once the organization has evidence that there is an acceptable period of time where no failures were found, the time between verifications can be increased. The new verification interval is then monitored. If an unacceptable level of failures is identified, then the verification frequency should revert back to the previous level.

5.2.4.5 Verifications

5.2.4.5.1 Types of verifications

There are several types of verifications in use by industry today. These verifications are often used in combination to maximize the effectiveness of the ESD control program.

5.2.4.5.2 Visual verifications

Visual verifications are used by many organizations to check the general state of the EPA. They can be used by employees at the start of the shift to ensure that all ground wires are in place and that unnecessary static generators have been removed from the workplace. Visual verifications can also be used by management and supervisory personnel to ensure that employees are following organization guidelines with respect to daily testing of wrist straps, the proper wearing of ESD control garments and the correct wearing of wrist straps and ESD control footwear. A visual verification is often a good indication of whether or not an ESD control program is being followed.

5.2.4.5.3 Measurement verifications

Most organizations rely on verifying that the ESD control items function through the use of actual measurements. These types of verifications are carried out by specially trained personnel using equipment that has been selected to properly measure each ESD control items. Some organizations measure 100 % of each control element in use throughout the factory while others perform verifications on a sample basis. The type of verification used is up to the organization implementing IEC 61340-5-1 as long as it proves to be effective.

5.2.4.6 ESD control item requirements

In the past, many organizations were forced to develop their own test procedures and establish the requirements for the ESD control items that they used. However, ESD control has advanced to the point where there are generally accepted requirements for many of the ESD control items that are used. Establishing an ESD control program around the requirements found in IEC 61340-5-1 will drastically reduce the possibility that ESD susceptible devices will be damaged by an ESD event.

There might be instances where it is necessary to tighten the requirements. An example of this situation occurs when the organization designs an ESD control program around a device with an ESD withstand voltage of less than the levels specified in the scope of IEC 61340-5-1.

5.2.4.7 Test methods

In order to implement IEC 61340-5-1, it is a requirement that the organization follows the test methods or standards specified in IEC 61340-5-1:2016, Table 1 to Table 3. It is recognized that some organizations have developed their own test methods or use other standard methods for verifying some of the ESD control items. This is allowed under IEC 61340-5-1. If the organization does not use the standards referenced in IEC 61340-5-1, a tailoring statement should be included in the ESD control program plan that describes the technical justification for not using the referenced standards.

The test methods listed in the tables are intended primarily for qualifying products and materials for use by an organization. A modified version of the test method is often used by the organization for making measurements that comply with IEC 61340-5-1.

It is very important that everyone involved in measuring the ESD control items understands how the measurements are to be made. The organization should select and document procedures for making each of the measurements. The organization should also ensure that everyone involved in taking measurements understands the testing procedures.

5.2.4.8 Test equipment

It is very important that the organization selects the proper equipment for making compliance verification measurements. It is best to select equipment that complies with the equipment specified in the individual IEC test methods or standards referenced in IEC 61340-5-1:2016, Table 1 to Table 3. Each of the technicians should be trained in how to properly use the measuring equipment.

5.2.4.9 Assessments

5.2.4.9.1 Assessor skills

As part of developing an ESD control program that is compliant with IEC 61340-5-1, it is important that the right people be selected to assess the ESD control program. Some considerations for selecting internal assessors include the following:

- The internal assessor should be familiar with IEC 61340-5-1 as well as the organization's specific ESD control program.

- The internal assessor should also understand how the ESD control program fits into the organization's quality management system. ESD assessment findings are one example. How does the organization handle non-conformances found during assessments? How are ESD assessment findings documented? Are corrective action reports generated? Prior to closing a corrective action, does the assessor verify that the audit finding has been corrected?
- It is preferred that the internal assessor has received training on how assessments are conducted.
- The ESD assessor should have a good understanding of the processes that they will be assessing.

5.2.4.9.2 Reporting of assessment findings

It is important to keep management informed about the status of the ESD control program. This can be accomplished through issuing reports at the completion of an assessment. The ESD coordinator will need to classify the severity of each non-conformance. Major non-conformances should be addressed before those considered to be minor in nature. For significant ESD non-compliance issues, management should be notified immediately so that proper resources can be assigned to correct the problem.

There are many ways to make management aware of the ESD findings. Assessment charts are commonly used to report the assessment results. The chart, at a minimum should identify:

- the number of findings;
- the type of finding;
- the area assessed.

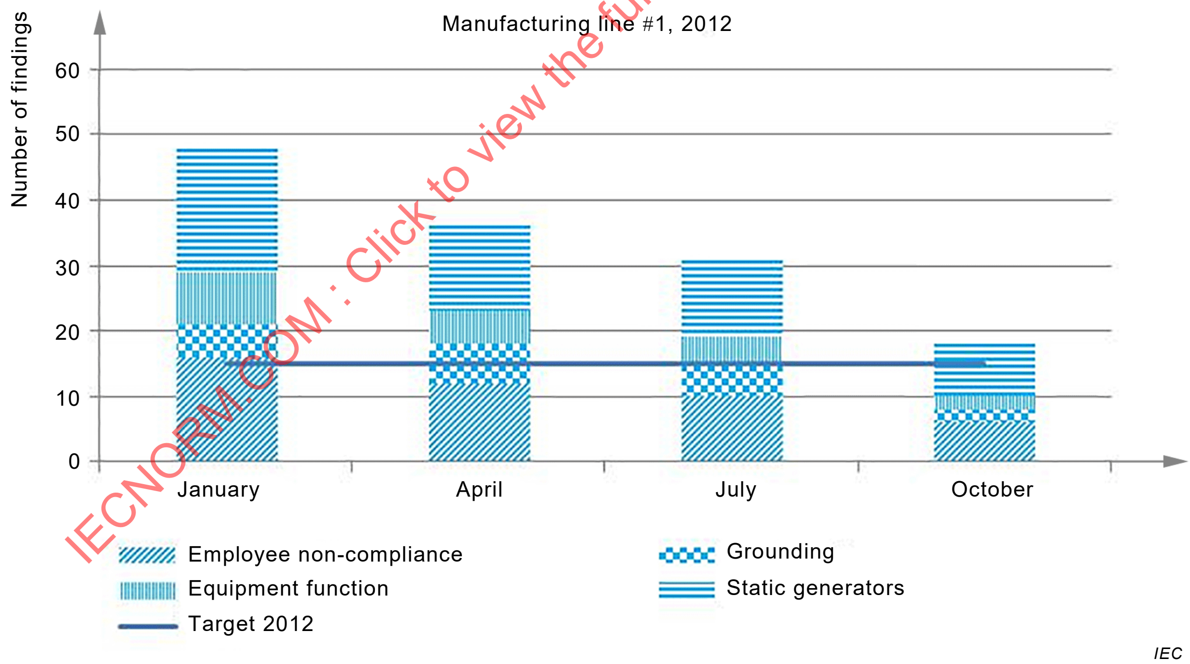


Figure 1 – Example assessment report showing trend report

The information contained in Figure 1 shows management the status of the ESD control program and the items that are the largest source of non-conformances, as well as the fact that the ESD control program is decreasing the number of findings. However the target level is not reached by October.

5.3 ESD control program technical requirements

5.3.1 Grounding/equipotential bonding systems

5.3.1.1 General grounding/equipotential bonding considerations

The protection of ESDS is accomplished by providing a ground path to bring ESD protective materials and personnel to the same electrical potential. All conducting items in the environment, including personnel, should be bonded or electrically connected to a known ground or common connection point. This connection results in a sharing of charge which equalizes the voltage across all items and personnel and eliminates the chances of an ESD event to ESD sensitive devices from those items in the bonded and grounded environment. Electrostatic protection can be maintained at a potential different from a "zero" voltage ground reference as long as all items in the system are at the same potential.

The upper limit of resistance to ground of the surface on which ESDS may be placed in IEC 61340-5-1, is less than the upper limit of resistance of some packaging material. Some materials, which are acceptable for packaging applications should not be used as a groundable surface when working on unprotected ESDS.

It is important to understand that insulators cannot lose their electrostatic charge by connection to ground. The handling of insulators is dealt with in 5.3.3 d).

The following subclauses are provides guidance and procedures needed to establish an effective path to ground. This discussion is limited to grounding for ESD purposes.

5.3.1.2 Basic grounding requirements

5.3.1.2.1 Common ground points and common connection points

The first step in ensuring that everything in an EPA is at the same electrical potential is to electrically bond all conductive components of the work area (work surfaces, people, equipment, etc.) to one of the following points:

a) common ground point connected to protective earth or functional ground, or

b) common connection point.

The layout and terminology used to define electrical power systems may vary between different regulations and standards, but the general principles should be similar. Nevertheless, organizations should consult IEC 60364-1 and national electrical codes/regulations before connecting any ESD control items to electrical power systems.

5.3.1.2.2 Grounding using protective earth

The preferred ESD ground utilizes the protective earth, also known as equipment grounding conductor, which is a part of the electrical power system. Using protective earth as ESD ground for ESD control items ensures that the ESD control items and all powered electrical equipment are at the same potential.

5.3.1.2.3 Grounding using functional ground

In situations where the organization does not wish to use the protective earth, or a protective earth is not available, a functional ground can be used. The functional ground is a separate earth grounding electrode that is used as the ESD ground for all the ESD control items used by the organization. It is recommended that, if possible, the functional ground system be bonded to the electrical ground system (when available) in order to eliminate differences in potential between the two grounding systems.

5.3.1.2.4 Common connection point (equipotential bonding)

Where a ground system is not available, an ESD control program can still be established by connecting all of the ESD control items and other large conductors together at a common connection point. The common connection point is not connected to ground, but the items attached to the common connection point will all be at the same potential, which minimizes the chance of the ESDS being damaged. The common connection point can be a single conductive point where the grounding wires of each of the ESD control items are attached or it can be a large conductive element such as the metal frame of a workstation.

A real life example of this is often observed in office equipment field service operations. For safety reasons, the service technician will often disconnect the AC power cord which detaches the equipment from ground. In order to install ESD sensitive boards or components into the equipment it is necessary to electrically connect or bond together the service technician, the equipment frame and the ESD sensitive product. Once bonded together, an ESD event will not occur between bonded items when the technician handles the product or installs it in the office equipment.

5.3.1.3 Additional grounding considerations

Aircraft, ships and surface vehicles typically have a ground bus or ground conductor that is suitable for use as an ESD ground. This scenario is similar to the equipotential bonding situation.

It is a good practice for each grounded work surface to be directly connected to common ground point. Figure 2 is an example of the recommended method. Many organizations however connect work surfaces to ground in series as shown in Figure 3. Connecting the work surfaces together in series can lead to a situation where multiple work surfaces become detached from ground if the single grounding wire breaks and therefore this type of grounding method is not recommended.

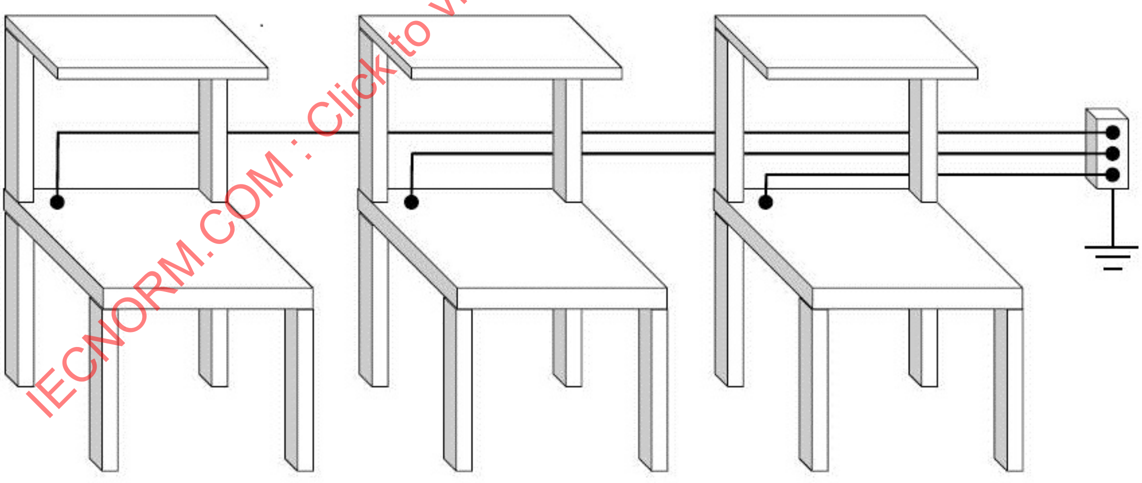


Figure 2 – Example of individually grounded benches – Recommended

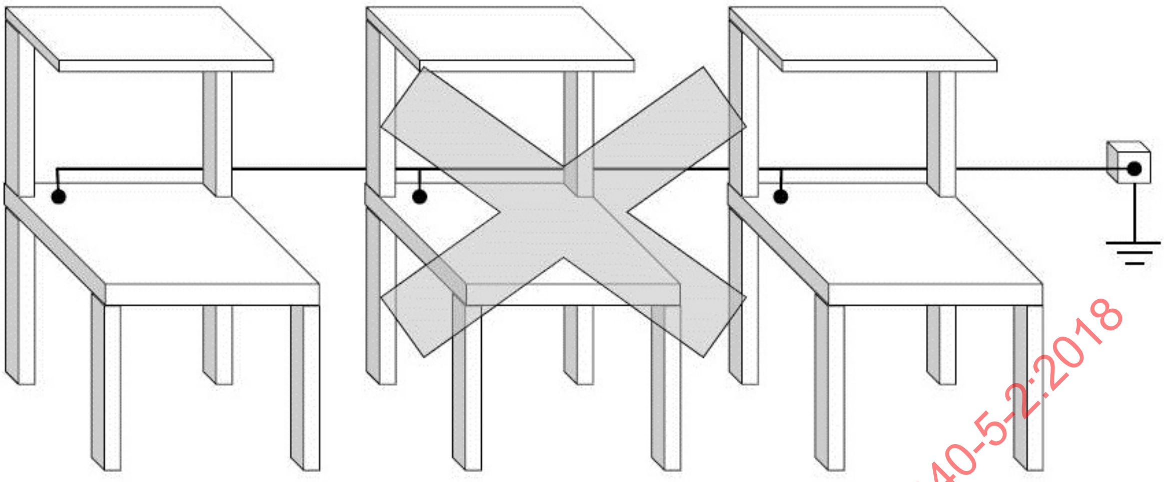


Figure 3 – Example of a series ground connection of benches – Not recommended

5.3.1.4 Verification of ESD grounding system

5.3.1.4.1 Protective earth

For ESD control programs that use the protective earth to ground the ESD control items it is necessary to verify the integrity of the electrical system. The values used can vary depending on the electrical code requirements in each country. However, there are certain items that should be checked for any ESD control program that uses the protective earth.

- The impedance of the protective earth should meet national electrical code requirements.
- The electrical system is correctly wired to ensure that the ESD control items are attached to ground and not to an energized portion of the electrical system.

5.3.1.4.2 Functional ground

When a functional ground is used it is necessary to verify that the ground rod system meets national electrical codes for such systems. If no code exists then measure the resistance between functional ground and protective earth and check that it complies with the specified value of IEC 61340-5-1.

5.3.1.4.3 Equipotential bonding

Where an equipotential bonding system is used, it is important to verify the electrical connection between common connection points.

5.3.1.5 Verification of proper installation of ESD control items

Once the ESD ground has been verified it is important to ensure that each of the ESD control items used is correctly connected to the ESD ground. Using the test method and limits for each ESD control item given in IEC 61340-5-1:2016, Table 2 and Table 3, verify that the resistance to ground (or to the common connection point) meets the required limit.

5.3.2 Personnel grounding

5.3.2.1 General grounding considerations

Personnel grounding is a critical technical element required in IEC 61340-5-1 and should be addressed any time personnel are involved with the handling of unprotected ESD sensitive devices. There are two means by which this requirement can be met. The first is by use of a wrist strap system and the second is by use of a flooring/footwear system. The choice is dependent on several factors that include the physical actions and surroundings of the individual as well as the potential cost of each alternative. Both system techniques include the person, the control items (i.e. wrist strap, flooring, and footwear) and the connection to ground. Wrist strap, flooring and footwear types, uses, and other key information about each are described in 5.3.2.2 and 5.3.2.3.

5.3.2.2 System requirements

Electrostatic charge can accumulate on the body through movement. The charge results in an electrostatic voltage between the body and ground. This charge can be damaging if discharged to ESDS. The procedures outlined in IEC 61340-5-1 are designed to protect devices sensitive to human body model voltages of 100 V or greater. To maintain a person's body voltage to less than 100 V, the body should be electrically connected to ground or differences in potential should be eliminated by bonding all of the ESD control elements together.

With a grounded system, there should be some degree of assurance that the body voltage remains below 100 V when connected in series with a resistance to ground. This resistance is a key factor in limiting the voltage observed on the body. For a given body movement, the voltage achieved increases with resistance. Tests have shown that a resistance of 3,5 x 10^7 Ω or less is necessary to limit body voltage for personnel using a wrist strap system to less than 100 V. Figure 4 shows the relationship between body voltage and resistance to ground for a given experimental setup. For an ESD control program that uses ESD control footwear and flooring to ground personnel, the situation is more complex. As people walk across an ESD control floor while wearing ESD control footwear, it is difficult to predict the voltage on a person's body due to the constantly changing body capacitance and the continuous charging and discharging of the person.

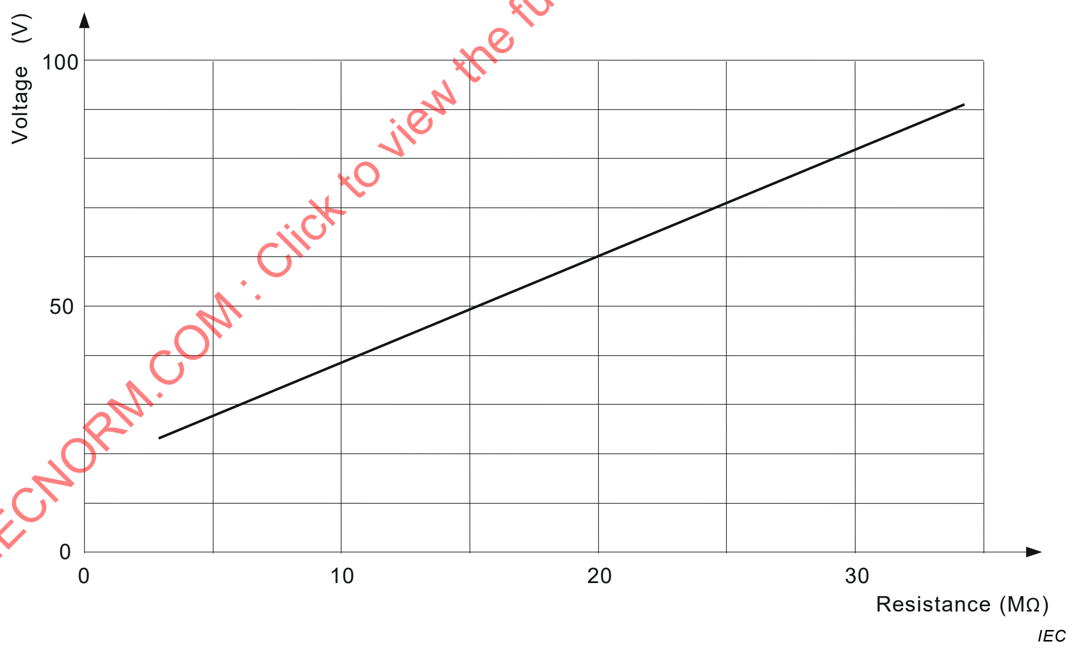


Figure 4 – Relationship between body voltage and resistance to ground

5.3.2.3 Wrist strap system

A wrist strap system consists of three elements: a person, a ground cord and a wrist band. To ensure that the resistance to ground of personnel is within the specifications, it is important to measure the entire system (i.e. from the person's body to the end of the ground cord).

A wrist strap assembly is the most commonly used means of grounding personnel. A wrist strap is required in IEC 61340-5-1 for operations where the individual is seated while handling or processing ESD sensitive items or components. The reason for this requirement is that floor and footwear systems may not provide reliable contact with ground since the person's feet may not be in contact with the floor at all times while seated.

While a wrist strap assembly will ground a person when standing, often the ground cord will become a physical impediment to the wearer. In these situations, organizations will often rely on a footwear-flooring system to ground their employees.

5.3.2.4 Footwear-flooring system

Personnel may also be grounded through use of a flooring and footwear system. This method is useful when personnel require mobility or stand in areas where wrist straps are not feasible and ESDS items should be handled or transported. The ground path is maintained through the use of dissipative or conductive floors and dissipative or conductive footwear. Footwear-flooring systems may be installed to provide a back-up ESD control item for personnel grounded with a wrist strap system.

When footwear-flooring systems are used as the only grounding system for personnel, the resistance to ground including the person, footwear, floor and body voltage generation needs to be less than specified in IEC 61340-5-1, under worst case environmental conditions. For this reason it is good practice to test at different times of the year when different humidity conditions may be experienced so that worst case conditions can be found.

For reasons such as safety, minimum resistance limits should be considered with reference to local regulations.

Some of the ESD control footwear options include ESD control shoes, sole and heel grounding straps and shoe covers. If the ESD control footwear does not completely cover the underside of the foot, charge generation may occur, especially when a person is walking. An example of this occurs with the use of heelstraps. The following chart (Figure 5) shows the voltage on a person's body as they walk across a grounded conductive floor while wearing two heelstraps. The voltage on the person's body is not controlled because the heelstrap is not in continuous contact with the conductive flooring surface.

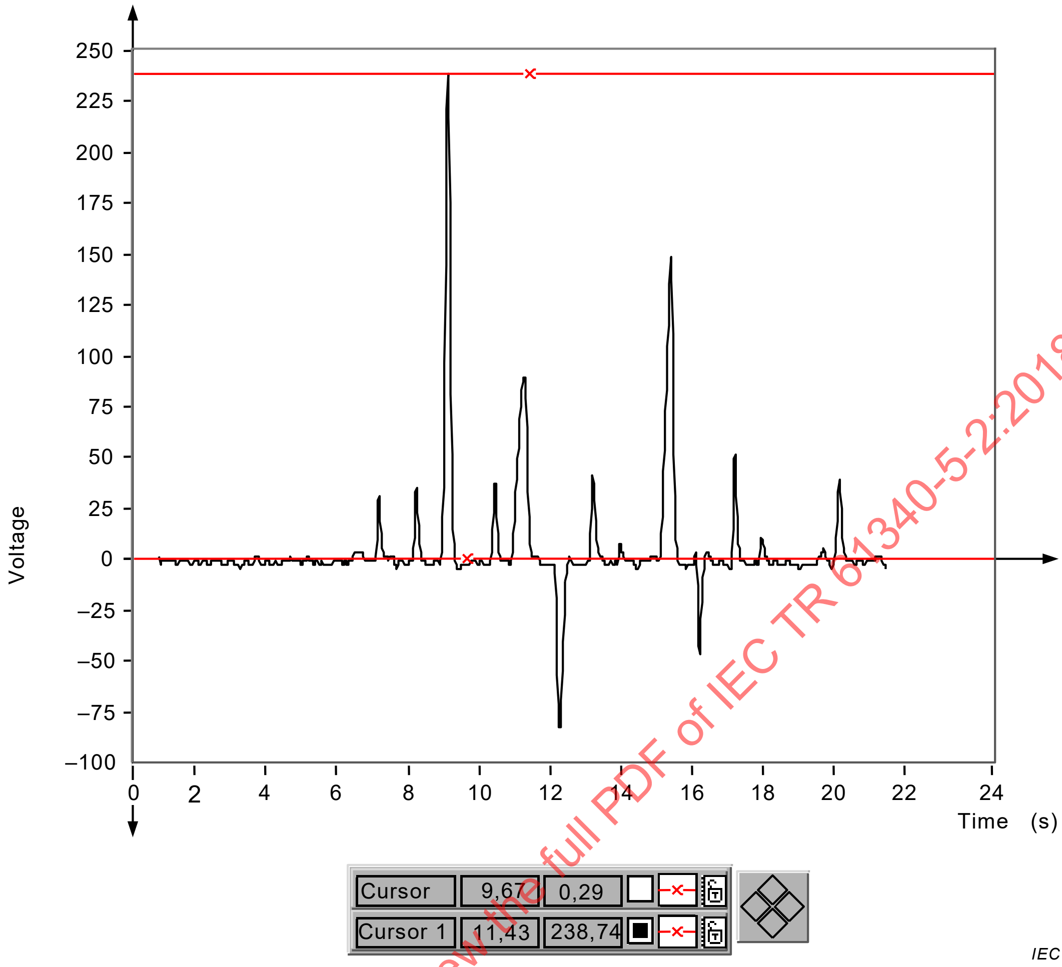


Figure 5 – Voltage reading on person walking across grounded conductive floor whilst wearing two heelstraps

Heelstraps can still be an effective part of an ESD control program when used for standing operations providing a strap is worn on each foot, and the ESD risk due to occasional loss of the ground connection is assessed to be acceptable. They should not be used in any process where unprotected ESDS are transported inside the EPA by hand.

Two complementary test methods are used to measure the footwear-flooring system in combination with a person and described in IEC 61340-4-5.

a) The first test method was developed to measure the electrical system resistance of floor materials in combination with a person wearing ESD control footwear. This test can be used to evaluate systems prior to installation or it can be used with installed floors. This test method can be used to characterize any ESD control floor material. These include all floor coverings (e.g. tiles, carpets, epoxies, laminates, mats, paints/coatings or floor finishes).

b) The second test method provides a way to characterize the ESD behaviour of floor materials and footwear by measuring the charge generation of the floor, footwear and person as a system. This test method can be used to evaluate systems prior to installation or it can be used with installed floors. This test method can be used to characterize any ESD control floor material. These include all floor coverings (e.g. tiles, carpets, epoxies, laminates, mats, paints/coatings or floor finishes).

5.3.3 ESD protected areas (EPA)

5.3.3.1 General considerations for EPA

An ESD protected area (EPA) is an area that is equipped with the ESD control items required to minimize the chance of damaging ESD sensitive devices.

In the broad sense, an EPA is capable of controling static electricity on all the items that enter that work area. Personnel and other conductive or dissipative items should be electrically bonded together and connected to ground (or a common connection point when a ground is not available) to equalize electrical potential among the items. The size of an EPA can vary greatly. An EPA may be a permanent workstation within a room or an entire factory floor encompassing thousands of workstations. An EPA may also be a portable worksurface or mat as used in a field service situation.

IEC 61340-5-1 places several requirements on the handling of ESDS as follows:

1) ESD sensitive devices should be handled inside an EPA. This means that at any operation where unprotected ESDS are handled, all of the items that potentially could come into contact with ESDS should either be connected to the defined ESD ground or connected together to form an equipotential bond. If the ESD sensitive device should leave the EPA, it should be protected from damage. ESD protective packaging or specially designed carriers can be used to transport ESDS from one EPA to another.
2) An EPA should have a well-defined boundary. Appropriate signs and markings should identify protected areas so that all people entering the area, including visitors, are aware that special precautions are needed. Some examples of appropriate signs/markings are physical signs, floor tape outlining the border of the EPA, different coloured floor tiles or any other method that defines the border of an EPA. The organization should ensure that ESD awareness training clearly describes to the new employees the rules for the EPA and how it is identified.
3) Access to the EPA is restricted to personnel who have trained on EPA protocols appropriate to their role in the EPA, for example cleaning personnel are trained not to handle ESDS when inside the EPA. This is sufficient training to enter the EPA in this case. In situations where suppliers, customers, new employees or other visitors need to enter into the EPA, they should be escorted by a person who has completed appropriate training.
4) The organization should ensure that the electrical potential on any isolated conductors that come into contact with ESDS will not exceed 35 V with respect to the ESDS.
5) All non-essential insulators need to be removed from the workstation or any operation where unprotected ESDS are handled. Insulators required as part of the manufacturing process need to be checked to determine whether or not they pose a threat to ESD sensitive devices.

5.3.3.2 Insulators

All non-essential insulators (plastics and paper) such as coffee cups, food wrappers and personal items should be removed from the workstation or any operation where unprotected ESDS are handled.

The ESD threat associated with process essential insulators should be evaluated to ensure that:

- the electrostatic field at the position where the ESDS are handled should not exceed 5 000 V/m or;
- if the electrostatic potential measured at the surface of the process required insulator exceeds 2 000 V, the item should be kept a minimum of 30 cm from the ESDS and;
- if the electrostatic potential measured at the surface of the process required insulator exceeds 125 V, the item should be kept a minimum of 2,5 cm from the ESDS.

These measurements are to be made based on the frequency defined in the compliance verification plan.

If it is not possible to maintain measured field at acceptable levels, the organization needs to use ionization or other methods to reduce the levels of charge generated in the process. The use of chemical treatments on the surface of insulating materials or the addition of humidity controls inside the EPA are two possible methods, in addition to ionization, that can be used to reduce the levels of measured electrostatic fields to acceptable levels. The general principles and guidance for measuring electrostatic fields and potentials of insulators are found in IEC TR 61340-2-2 and IEC TR 61340-1.

5.3.3.3 Isolated conductors

Isolated conductors that come into contact with ESDS should be avoided when possible. An ESD control item should not have ungrounded conducting parts or insulators. When establishing an ESD control program plan, if a conductor that comes into contact with an ESDS cannot be grounded or equipotentially bonded together, then the process should ensure that the difference in potential between the conductor and the contact of the ESDS is less than 35 V.

NOTE The 35 V limit is related to the level achievable using the ionizers specified in IEC 61340-5-1 (see also 5.3.3.4.6 in this document).

This can be accomplished by measuring the ESDS and the conductor by using: a non-contact electrostatic voltmeter or a high impedance contact electrostatic voltmeter.

Examples of possible isolated conductors are; test probes, bond wires, hand tools and transport rollers,

5.3.3.4 ESD control items

NOTE Subclauses 5.3.3.4.1 to 5.3.3.4.9 describe some of the various ESD control items that can be used when developing an ESD control program that is compliant with IEC 61340-5-1.

5.3.3.4.1 Work surfaces

5.3.3.4.1.1 Introductory remarks

Work surfaces play a critical role in the design and implementation of an EPA. Work surfaces designed for ESD control are used in production and repair areas as well as in field service. Most areas where unprotected ESDS are handled, repaired or tested require some form of a work surface designed to dissipate electrostatic charges. The work surface is a major component in establishing a local static safe work environment. The work surface is considered by most of the industry to be the second most important element of an ESD control program, personnel grounding being most important.

The main purpose of a properly grounded work surface is to ensure that the items being handled and the work area are at the same electrical potential. Work surfaces provide the following functions:

- a work surface designed for control of static electricity provides an electrical path to ground or a common connection point in the case of an equipotential bonding situation. This allows non-insulating items placed on the work surface to discharge in a controlled manner;
- in some cases the work surface defines the boundary of an ESD work area in which ESDS can be handled.

5.3.3.4.1.2 Factors in selecting work surfaces

There are several factors to be considered in selecting an appropriate work surface. The major factors are the following:

- work area activities;
- permanency of the work area;
- physical considerations;
- chemical considerations;
- electrical considerations;
- safety considerations;
- material maintenance.

5.3.3.4.1.3 Work area activities

The type of work being performed at the location will determine the type of work surface that is required. If the items being handled are sensitive to mechanical shock, then a cushioning work surface material may be required. If heavy products with sharp edges are moved around the work surface, then a more durable surface may be necessary. Operations where personnel are exposed to high voltages may require the use of work surfaces that will limit the current if the power source comes into contact with the work surface. Work surfaces used in cleanrooms may also require special consideration, including particulate contamination and outgassing properties. Flammability of work surface materials may need investigation to satisfy corporate requirements, insurance carriers, or safety ratings.

5.3.3.4.1.4 Permanency of the work area

In selecting work surface materials, a good understanding of the operation is necessary to ensure that the correct materials are selected. Considerations include the following:

- Field service activities often necessitate a completely portable work surface that may fit in a tool kit or pocket of a field service engineer. This work surface should be designed so that it can withstand continual handling and frequent connection and disconnection from ground. The work surface might also need to last for years in the service engineer's tool kit.
- Overspray or spillage of conformal coating chemicals, which may be applied to PCB for example, can increase the work surface's resistance to ground to the point where the work surface may no longer function. For these situations a disposable work surface might be more cost effective.

5.3.3.4.1.5 Physical considerations

Most work surfaces require a degree of durability. Durability factors that should be considered are hardness, abrasion resistance and tear resistance. Some work surfaces may require special heat-resistant materials. Soldering stations, for example, may need work surfaces designed to resist heat.

Appearance is often an important factor in selecting a work surface. Colours also may be used to distinguish specific operations or establish corporate identity. Light reflection may be an important ergonomic consideration. Portable work surfaces should lay flat on the substrate. Curling with age should be a characteristic that is investigated during the qualification process. Functionality, durability and reliability of the work surface grounding system should be evaluated during qualification testing.

5.3.3.4.1.6 Chemical considerations

Chemical transfer from the work surface may cause contamination that could lead to corrosion of sensitive metallic parts. Solvents and other chemicals handled at the workstation may have deleterious effects to the work surface. The work surface material should be evaluated for required compatibility during the qualification process.

5.3.3.4.1.7 Electrical considerations

The most important functional consideration for work surfaces is the resistance from the top of the surface to the groundable point. This establishes the resistance of the primary path to ground for items placed on the surface. IEC 61340-5-1 has set a resistance to ground range for work surfaces of less than 1,0 x 10^9 Ω.

Where charged device model (CDM) damage is a concern, IEC 61340-5-1 recommends a minimum point-to-point resistance of 1,0 x 10^4 Ω.

5.3.3.4.1.8 Safety considerations

Workstations with hazardous electrical potentials may require significantly different electrical properties. The resistance to ground and point-to-point resistance values may need to be increased where line voltage is present.

NOTE DC resistance measurements might not be adequate for making electrical safety decisions.

5.3.3.4.1.9 Types of work surface materials

5.3.3.4.1.9.1 General

A wide variety of work surface materials and forms exist, with more being developed all the time. The properties of these different materials vary (mechanical, physical, and electrical). Even though there are many varieties of work surfaces, two basic classes of work surface materials are available. These basic classes are generally called mono-layer and multi-layer. Some work surfaces, particularly mono-layer and high pressure laminates, may have some degree of humidity dependence. These materials should be tested for acceptable performance at low humidity prior to selection and installation. If a minimum resistance is specified, either for electrical safety reasons or because CDM damage is a concern, additional testing should be done at high humidity.

5.3.3.4.1.9.2 Mono-layer work surface materials

Mono-layer or homogeneous work surface materials are those that have the same electrical and physical properties throughout the bulk of the material. Rigid surfaces and flexible mat type materials are available in different resistance ranges. Point-to-point resistance (R_{p-p}) and resistance to ground (R_g) measurements may change with distance between the electrodes or between the electrode and the groundable point of the work surface.

5.3.3.4.1.9.3 Multi-layer worksurface materials

Multi-layer worksurface materials typically consist of two or three distinct layers. The top surface is normally a layer of dissipative material, varying, by product, in thickness and electrical properties. The next layer is generally highly conductive. Some forms have a bottom layer that is made from either insulating or dissipative materials. Electrical resistance from point-to-point and resistance to ground are generally consistent, regardless of the distance between electrodes or between a single electrode and the worksurface's groundable point. The controling factor is the vertical resistance through the top surface to the conductive layer. Proper connection of the groundable point hardware to the conductive layer is critical to ensure proper charge dissipation.

5.3.3.4.1.9.4 High-pressure laminates

These materials are rigid and are applied to a substrate, typically with adhesive systems. The majority of these materials follow the multi-layer description above. There are, however, some types that are basically homogeneous in construction.

Because the electrical properties of many high-pressure laminates have some degree of humidity dependence, all high-pressure laminate materials should be carefully tested for acceptable performance at low humidity prior to selection and installation. If a minimum resistance is specified, either for electrical safety reasons or because CDM damage is a concern, additional testing should be done at high humidity.

5.3.3.4.1.9.5 Mat and runner (rolled) materials

Mat and runner materials are generally flexible systems that are used to cover non-ESD control substrates. Another common application is to use mats on top of ESD control high-pressure laminates to provide a less humidity-dependent surface in environments where relative humidity varies by season. Mats and runners are available in a range of resistance values and in mono-layer and multi-layer types.

5.3.3.4.1.9.6 Field service/portable work surfaces

Portable work surfaces in a variety of forms (mono-layered or multi-layered) are available to meet established requirements and the same ESD control needs as those used in non-remote areas. Typically, field service work surfaces are designed to fold up and fit in a tool kit or a pocket of a field service engineer.

5.3.3.4.1.10 Testing

A procedure that can be used for testing the electrical resistance of work surface materials can be found in IEC 61340-2-3. Use the test method described for making point-to-point resistance and resistance to ground or groundable point measurements.

5.3.3.4.1.11 Qualification

As part of the selection process, work surface samples are often qualified under laboratory conditions where parameters such as humidity, temperature and test voltage are controlled. Unless otherwise specified, test parameters specified in IEC 61340-2-3 and IEC 61340-5-1 should be used.

5.3.3.4.1.12 Initial installation or acceptance

When first installed, work surfaces should be tested to make certain that they are functional and meet specifications. Typically, the resistance from the top of the work surface to ground is measured to ensure that the work surface has been properly installed. Verifying that the work surface is connected to ground should be carried out before ESD sensitive devices are handled on the work surface. It is recommended that point-to-point resistance measurements be made after installation in order to understand the characteristics of the material.

5.3.3.4.1.13 Periodic tests

Periodic testing of work surfaces is necessary to ensure that they continue to meet specifications. Resistance to ground measurements are typically used to verify that the path to ground is intact. In cases where the resistance to ground measurement exceeds the established resistance limits, the following steps can be taken to identify the cause of the high resistance readings:

- Verify visually that the work surface is connected to the ground.
- Clean the work surface and the contact surface of the resistance measuring electrode. Sometimes a dirty surface can cause the resistance to exceed acceptable limits. Once the surface has been cleaned and allowed to dry, if a liquid cleaner is used, repeat the resistance to ground measurement. If the second measurement is within specification this might lead to a further investigation concerning the cleaning practices used by the organization.
- Disconnect the grounding wire and measure the resistance from the top surface of the work surface to the work surfaces groundable point. This measurement will show whether or not the work surface is functioning as designed and it will verify that there is a good connection between the groundable point and the work surface.

- Using an ohmmeter, measure the resistance of the wire used to ground the work surface. The measurement is made from the point where the wire is connected to the work surface's groundable point to the ground.

The frequency of periodic testing is normally specified in the organization's ESD control program plan/compliance verification plan. It can depend on many factors such as established reliability of the installation, usage, possibility of contamination.

5.3.3.4.1.14 Maintenance

Periodic cleaning, following the manufacturer's recommendations, is required to maintain proper electrical function of all work surfaces. Ensure that the cleaning products used do not leave an electrically insulating residue which is common with some household cleaners that contain silicone.

5.3.3.4.2 Wrist straps

5.3.3.4.2.1 General description

The wrist strap is a device used to keep personnel at the same electrical potential as the ESD sensitive item(s) they are handling. In most cases this is affected by a connection of both the person and ESDS to ground or to a common connection point when an equipotential bonding system is used. Subclause 5.3.3.4.2 covers practical information for the use, care and periodic checking of wrist straps.

Wrist straps typically consist of a band which makes contact with the wearer's skin. The band is then attached to a ground cord which is connected to the ESD ground.

5.3.3.4.2.2 Band

The band is a flexible, form-fitting device designed to make a reliable continuous connection to a person's wrist. Bands are manufactured in many types as summarized in Table 1.

Bands almost always have a hypoallergenic metal plate, usually stainless steel, under the buckle or snap head to ensure good skin contact. The remainder of the band generally has a conductive skin-contacting surface. This ensures that there is complete 360° of contact between the band and the person's skin with this type of band. While other designs also exist that may not have 360° of contact, those that do are the most prevalent in use today.

Bands may have a quick-parting, electrical-mechanical connector that mates with a corresponding connector on the head of the ground cord. This connector serves two purposes. First, it is a physical connection for attaching the ground cord. Second, it is the groundable point on the band. Quick release is an important feature of the connector. The breakaway force should be low enough to allow easy release, but high enough to prevent unintentional disconnection. If the breakaway force is too light, the ground connection could be lost without the knowledge of the wearer. Experience has shown that for conventional, single-conductor wrist straps, connectors that part with a force of 13 N to 36 N are satisfactory.

When initially selecting wrist straps or when reordering for an existing program, it is a good practice to specify a compatible snap size and orientation. This allows for compatibility between existing wrist straps and new purchases. Many wrist strap manufacturers will customize the snap connector configuration to suit the user's requirements provided there is sufficient quantity.

Table 1 – Types of bands

Woven elastic fibre with conductive fibres on the inside surface
Knit elastic fabric with conductive fibres on the inside surface
Woven non-elastic fabric having a conductive inside surface
Metal expansion bracelet with insulating resin on the outside surface
Plastic resin wrist watch band with stainless steel sheet metal strips on the inside surface
Shaped sheet metal bracelet with insulating resin on the outer surface
Electrode patch with conductive adhesive

5.3.3.4.2.3 Ground cord

The ground cord is a wire assembly that connects the wrist band to ground or to a common connection point. It usually consists of an insulated wire with a connector head that attaches to the band on one end and a termination device on the other end for connecting to ground. Ground cords usually contain a current-limiting resistor at the band-connecting end.

At first glance, the ground cord appears to be a relatively simple assembly. However, the design requirements are considerable, given the wide range of user applications and the durability requirements of constant tugging, flexing and dragging over the edge of workstation tops and equipment chassis.

Ground cords are available in varying lengths, straight wire or retractable coil cords, resistors in one end or both ends, various colours and several types of ground termination devices. The wire can be multi-stranded linear or helical wound tinsel. The insulation can consist of a durable polymer, a tough synthetic rubber or vinyl.

Any electrical connector that can be attached to ground is acceptable as long as it is mechanically durable. The preferred grounding point for the groundable end of the cord is a common ground point or common connection point (see 5.3.1 for further information).

Many wrist strap users have been observed to clip the ground cord to the edge of an ESD protective mat. This process is not recommended as it can increase the total system resistance to ground to over the 3,5 x 107 Ω limit required by IEC 61340-5-1.

5.3.3.4.2.4 Wrist strap use and selection

5.3.3.4.2.4.1 Limitations of use

The wrist strap is an effective system for grounding people who handle ESD sensitive materials. However, it is important to emphasize that while the wrist strap grounds the skin, it does not provide a means to eliminate static charges from clothing and footwear, unless these items are conductive or dissipative and make contact with the person's skin.

5.3.3.4.2.4.2 Wrist strap use

For maximum effectiveness, wrist straps should be used properly following these guidelines.

- The wrist strap band should fit snugly and make full skin contact around the wrist. The wrist band should not be worn uncomfortably tight and should not leave deep marks on the wrist.
- The wrist strap should be connected to a common ground point or a common connection point. A continuous and secure connection will provide the proper dissipation of electrostatic charges stored on the body.

5.3.3.4.2.4.3 Wrist strap selection

The following factors should be considered when selecting and evaluating wrist straps:

- reliability;
- durability;
- length of the ground cord;
- retractable ground cord or straight;
- snap configuration;
- ground termination connector;
- comfort.

Human comfort plays a major part in the selection of a wrist strap design since the wrist strap has to be worn continuously. It should not detract from the efficiency of any work function. There are numerous designs that incorporate various techniques for providing reliable skin contact. These wrist straps range from fabric woven with conductive fibres to metal flexible bands or other special use designs. The ultimate selection will be up to the user since it should be compatible with the process.

5.3.3.4.2.5 Wrist strap testing

Because wrist straps do not last forever, they should be tested periodically. A good testing program not only tests the wrist strap itself, but also indicates the quality of the skin contact when performing a system test. Wrist strap bands that are soiled, incorrectly sized or improperly worn will show resistance higher than acceptable. Changes in weather and people can affect ground resistance. Dry skin often leads to high resistance indications.

5.3.3.4.2.6 Reliability testing

A major factor in selecting and using wrist straps is reliability. Stress testing to predict reliability is expensive and best performed by a qualified laboratory.

Analysis of the wrist strap to determine the nature of the failure can be useful. Areas of concern include skin contact failure, ground cord failure and connector failure. By collating the data on a periodic basis, it is possible to determine trends for particular manufacturers and styles. This information will be useful when making further purchasing decisions. Use of wrist straps that exhibit inadequate life span should be discontinued, regardless of the failure mode.

5.3.3.4.2.7 Additional user wrist strap testing

The testing described here is more than a test of a wrist strap; it is also a test of the quality of the connection the band makes with the wrist. It is a test of the wrist strap in an ‘as used’ configuration, referred to as a system test. The purpose of testing the wrist strap as a system is to confirm that the total series resistance of all of the elements in the system is between the minimum and maximum resistance allowed by the user's specification.

Proper testing of the wrist strap includes the resistance of the groundable point on the end of the ground cord, the cord itself, the current-limiting resistor, the cord-to-band snap connector, the resistance of the interface of the cuff, the cuff/wrist interface, and the resistance of the person between the wrist and the hand that contacts the test electrode. The maximum acceptable resistance for wrist strap grounding is $3,5 \times 10^7$ Ω. There are many commercially available wrist strap checkers to perform this system test. Some have the added capability to test the cord alone. When selecting a wrist strap checker, it is important to read the specifications to see if the upper and lower resistance limits of the checker match the user’s requirements. On some wrist strap checkers, one or both limits may be adjustable. In use, these checkers will indicate if the system resistance is below, above, or within the acceptable range. Some testers will only indicate whether the system resistance is within the acceptable range or outside it.

A system test can also be performed using an ohmmeter as long as the test potential is safe. A metal electrode that can be held in the hand is attached to one of the meter leads. Holding a pin probe tip between fingertips can produce erroneous results. When using an ohmmeter to perform this test, it is important to understand that the resistance of the human is considered in the total resistance of the system and that the value of this resistance will vary from person to person.

5.3.3.4.2.8 Test procedure

While wearing the wrist strap, connect the loose end of the ground cord to the tester terminal and depress the test button or touch the metal test surface with a finger or hand. If the resistance is over 3,5 x 10^7 Ω, test the cord alone for continuity. If the resistance of the cord alone is approximately 1,0 x 10^6 Ω, check the fit of the band around the wrist and adjust it for a snug fit. Snap the cord back on the cuff and retest. If the resistance is still over 3,5 x 10^7 Ω, substitute a new band. Electrical breakages within the cord can be checked by flexing the cord during measurement.

If the resistance is still too high, dry skin might be the problem. Dry skin conditions can be resolved by applying moisturizing lotion on the wrist and repeating the resistance test again. The moisturizing lotion should be one that is compatible with process requirements and does not cause contamination.

NOTE Metal expansion bracelet style wrist bands can trap moisture underneath and can be more effective for people with dry skin.

5.3.3.4.2.9 Test frequency

Wrist straps should be tested periodically. The frequency of testing, however, is driven by the amount of usage, wear and ESD risk exposure that can occur between tests. For example, what is the quantity of product handled between test periods?

Because wrist straps have a finite life, it is important to develop a test frequency that will guarantee integrity of the system. Typical test programs recommend that wrist straps that are used daily should be tested daily. However, if the products that are being produced are of such value that a guarantee of a continuous, reliable ground is needed then continuous monitoring should be considered or even required.

Data taken from the test program will ultimately allow the user to make the choice of how often the wrist strap should be checked and which wrist straps have the most useful service life.

5.3.3.4.2.10 Current limiting

Wrist straps have a current limiting resistor moulded into the ground cord head on the end that connects to the band. The resistor most commonly used is a 1 x 10^6 Ω, 0,25 W with a working voltage rating of 250 V. Resistors limit current as defined by Ohm's Law, which states the current is equal to the voltage divided by the resistance. In a practical application, the maximum amount of current through a wrist strap ground cord if it is placed across a 250 V source, is 250 μA or 0,25 mA.

If personnel are exposed to high voltage then the appropriate procedures to mitigate risk should be used.

5.3.3.4.2.11 Constant/continuous wrist strap monitors

A functioning wrist strap system, which is properly connected to ground, will keep an operator at a value close to ground potential. The periodic testing of wrist straps (typically on a daily basis) as described in 5.3.3.4.2.8 verifies that the wrist strap system is being properly worn and is functioning as expected. However, if any part of the system were to fail for any reason the operator would not know of the failure until the system is next tested (typically on the next shift). If a wrist strap system were to fail between test cycles this could lead to the charging of personnel and potentially damaging any device that is handled. If this were to happen, all ESDS material processed between tests becomes suspect.

Constant/continuous monitors were developed to overcome this situation and are often required in critical operations (very sensitive devices or high value product applications). Constant/continuous monitors are in general testing the electrical connections between grounding point, ground cord, band and body during normal operations. Audible and/or visual alarms indicate possible failures are brought to the attention of the operator.

5.3.3.4.2.12 Different type of wrist strap monitors

5.3.3.4.2.12.1 General

There are different types of constant monitors sold in the market today. All are designed with the intention of notifying the operator of a wrist strap system failure. Subclasses 5.3.3.4.2.12.2 to 5.3.3.4.2.12.5 describe the various monitors that are being marketed today.

5.3.3.4.2.12.2 Capacitance constant monitor (single wire)

When a person is connected with a single wire wrist strap to the capacitance constant monitor, the monitor circuits detect the person and his relation to ground. The person's body capacitance to ground is used as a return path for an AC sensing signal. A benefit of this approach is that both the wrist strap–body connection as well as the monitor ground connection are tested. Disadvantages are that the monitor may have to be adjusted for each individual and that false alarms can be produced by changes other than a poor fitting wrist band or broken wire.

5.3.3.4.2.12.3 Impedance constant monitor (single wire)

This type of monitor is working on the same principles as the capacitance monitor, however to overcome the disadvantage of the capacitive monitor a detection circuit is imbedded to eliminate adjustments and to reduce false alarms. The phase difference between current and voltage of a very low AC current is used to detect impedance changes in the loop: ground cord, band and wearer.

5.3.3.4.2.12.4 Resistance constant monitor (dual wire)

The principle of operation of these monitors is based on observing the resistance of the loop ground cord, one part of the wrist band, operator skin, other part of the wrist band and second ground cord. If one of the parts in this loop comes outside the specified limits, or even worse opens, an alarm is given. To avoid skin irritation due to the constant application of DC voltage (which is used for sensing) some DC wrist strap monitors utilize a pulsed signal. The applied voltage to the wrist strap can vary from <1 V DC to 16 V DC depending on the monitor's design. This is a point of consideration when working with very sensitive ESDS.

5.3.3.4.2.12.5 Body voltage constant monitor (dual wire)

The voltage on a person's body is sensed by use of a dual wire wrist strap and compared with a pre- selected value in the constant monitor. A disadvantage of this approach is that in case of an open circuit no unwanted voltages on the wearer are detected. To avoid this disadvantage in the new designs an impedance or resistance wrist strap monitoring circuitry is also incorporated.

5.3.3.4.2.13 Test procedure for constant monitors and accompanying wrist straps

The single as well as dual wrist straps used in combination with the constant monitors can be checked for performance by resistance measurements as described under wrist strap testing. Most of the constant monitors have, depending on the brand, a dedicated tester which test the limits and proper operation of the monitor. Since the principle of constant monitors is to transmit an electrical signal via the wrist strap to the wearer to determine the continuity of the whole grounding system the maximum level of this signal is a point of concern and has to be measured to avoid critical situations.

The principles of these measurements are as follows.

- Measure the open circuit voltage on the wrist strap when installed according to the manufacturer's instructions.
- In case of a dual wire wrist strap both halves of the wrist strap band have to be measured; measure the induced voltage of the constant monitor on the wearer, when the person under test is standing on an insulator and holding an electrode which is connected to the measurement equipment.

5.3.3.4.2.14 Summary

- Wrist straps provide an effective means for maintaining personnel at ground potential or at the same potential as the item(s) being handled. People who are at ground potential or a potential the same as the ESDS they are handling, cannot discharge to the ESDS when it is handled or touched.
- Wrist straps usually have a current-limiting resistor, typically 1,0 x 10^6 Ω, molded into the ground cord near the point where the cord attaches to the cuff. The resistor usually has a working voltage rating of 250 V.
- Wrist straps are sometimes supplied with a 1,0 x 10^6 Ω resistor molded into both ends of the ground cord when both ends of the cord have the same type snap connector.
- Wrist straps should not be worn by personnel where they could come into contact with voltage over 250 V.
- The ground cord of the wrist strap should have a quick release connector to the cuff so personnel will not be tied to the workstation.
- The band of the wrist strap should be worn comfortably snug around the wrist while making full skin contact.
- The ground cord of the wrist strap should be connected to a common ground point or a common connection point. Do not connect to a snap on a dissipative mat unless it is the groundable point for the mat. Do not clip a wrist strap to the edge of a dissipative mat.
- Wrist straps should be tested on a regular basis with daily testing being recommended.

5.3.3.4.3 Static protective floor materials

5.3.3.4.3.1 Introductory remarks

A common cause of static electricity is the movement of people and materials in the work environment. The contact and separation of shoes from floors generates body voltages as high as several thousand volts. Similarly, the movement of mobile carts or other equipment will generate electrostatic charge. Subclause 5.3.3.4.3 will review the use of floor materials to dissipate electrostatic charge. It will cover floor coverings, floor finishes, topical anti-stats, floor mats, paints and coatings.

5.3.3.4.3.2 Functions of static protective floor materials

Static protective floor materials are used in the industry for:

- grounding of personnel (floor materials can be used in combination with ESD control footwear as either a primary ground or a secondary, backup, grounding system for wrist straps in critical processes),
- grounding of ESD control items such as:
  - mobile carts,
  - ergonomic stands used to raise the product to an employee's working height,
  - workstations,
  - seating.

Floor coverings, mats, paints and coatings help control static charge by providing a path of moderate electrical conductivity from the human body or ESD control item to ground. Many flooring products use a conductive material, such as carbon, metal or other additives, that extends from the surface of the material to an underlying substrate such as conductive adhesive. The floor material is then connected directly to ground.

Floor finishes and topical anti-stats, on the other hand, function by two separate mechanisms. First, they reduce the surface's tendency to generate a static charge. Second, they provide a path for the dissipation of charge. If the floor finish or topical anti-stat is used for primary grounding it needs to limit charging while dissipating it to ground.

5.3.3.4.3.3 Grounding personnel using footwear-flooring

Grounding through the floor is dependent on the type of footwear that is in contact with the floor. Typical street or industrial footwear have insulating rubber, crepe, or polyurethane shoe soles. These materials insulate the wearer from the floor and generated charges cannot readily flow from the body, through the insulating shoe sole and the floor material to ground.

Studies of ESD control floor materials indicate that charge generation and dissipation rates measured on a person's body vary with the type of footwear worn as well as the floor material. The levels of performance depend upon the combination of floor material and footwear. The proper selection of footwear flooring combination is critical to achieving the required performance of static protective floor materials.

5.3.3.4.3.4 Benefits of floor materials

The main benefit with floor/footwear systems is to give the operator continuous, reliable grounding with freedom of movement within the working area. The floor helps to incorporate several independent EPA workstations to a single working area. It provides a means of grounding chairs, trolleys and other mobile equipment.

5.3.3.4.3.5 Limitations of floor materials

Floor materials also have some limitations. When used to ground people, it is important that the person maintains electrical contact with the ESD control floor at all times. In order to do this the person should have foot contact with the floor. This is the primary reason that IEC 61340-5-1 requires a wrist strap for seated operations.

The use of floor materials may be limited by installation considerations. For example, concrete floors may contain excessive amounts of moisture which may restrict the installation of resilient floor coverings. ESD control carpets might not be practical for processes where there is excessive water spillage.

Some static protective flooring materials cannot withstand the weight of heavy vehicles such as forklift trucks.

Some materials may be restricted from certain applications in the facility due to process considerations. An example could be a floor finish that introduces contaminants to the environment and would not be usable in a clean room.

Excessive amounts of dirt on a floor material can have a negative effect on the performance of the floor material by charge generation and dissipation properties. It is important that floor materials be cleaned on a regular basis. It is also important to ensure that the proper cleaning procedures and products are used to ensure that the performance of the floor is not compromised.

When selecting static protective flooring, it is important to consider the needs of the entire process.

5.3.3.4.3.6 Types of floor materials

Floor material options can generally be classified into permanent and semi-permanent or non-permanent materials. Some of the major advantages and disadvantages of each material type are discussed below. These following floor material types are examples that are on the market. Other types might be available or developed in the future.

5.3.3.4.3.7 Permanent floor materials

5.3.3.4.3.7.1 General description

Permanent materials are broadly defined as floor coverings, including rubber or vinyl tile and sheet goods, epoxy coatings, high-pressure laminates, and carpet. As a group, these materials have an extended use life and provide protection over a broad physical area.

5.3.3.4.3.7.2 Rubber and vinyl tile and sheet goods

Resilient floor coverings are the most frequently used permanent floor materials. The material composition is usually rubber, vinyl, or vinyl composition. Material form can be either tile or sheet. Resistance ranges are typically from 10^4 Ω to 10^9 Ω point-to-point or resistance to ground. Resilient floor coverings offer resistance to many commonly used chemicals. Most materials can be welded and self-coved for seamless installation in clean rooms. They can be applied to raised floors. Vinyl floor materials may require more maintenance than other permanent flooring alternatives; rubber flooring requires somewhat less maintenance than vinyl. Some resilient floors may be slippery, particularly when wet. They may be adversely affected by heavy vehicular traffic. The presence of carbon in some of these materials may restrict their use in some clean room applications, although the abrasion resistance of these materials is quite good. Additionally, vinyl flooring systems may outgas and may not be applicable in some clean rooms.

5.3.3.4.3.7.3 Epoxy and polymeric coatings

Generally a poured permanent flooring material, these products are frequently 3 mm or more in thickness, but also can be installed in a thinner gauge (see 5.3.3.4.3.8.5). They have good chemical, solder, and abrasion resistance and will withstand heavy vehicle traffic. They are easier to maintain in comparison to other materials. They are seamless and can be used in many clean room environments. However, they cannot be used on raised floor panels. Because epoxies are virtually manufactured on-site, proper installation techniques by experienced installers are critical to the successful performance of this type of material.

5.3.3.4.3.7.4 High pressure laminates

Similar to the popular work surface materials, these products are normally limited to raised floors or as floor mats. Laminates tend to be moisture sensitive and should not be used in areas of high chemical or water spillage or directly on concrete sub-floors that may be subject to high levels of moisture. Changes in humidity may change the resistance characteristics of these materials. High-pressure laminates also lack the physical flexibility to be installed on most standard sub-floors.

5.3.3.4.3.7.5 Carpeting

Carpeting is available in resistance ranges of 1 x 10^4 Ω to 1,0 x 10^{13} Ω. It has aesthetic and acoustical benefits and is a morale booster to employees. Maintenance costs tend to be lower on carpeting than on resilient floor materials. In the form of carpet tiles, it can be used on raised floor panels. Carpet, however, is not well suited for use in area's subject to excessive soiling, water and chemical spills, exposure to significant amounts of hot solder, heavy vehicular traffic or in clean rooms.

5.3.3.4.3.8 Semi-permanent or non-permanent materials

5.3.3.4.3.8.1 General description

The second group of floor materials is described as semi-permanent or non-permanent and includes interlocking tiles, mats, floor finishes, topical anti-stats, and paints and coatings. Their life expectancy is less than that for permanent materials and they require periodic re-treatment or replacement. The single most striking characteristic of these materials is their flexibility and ease of use.

5.3.3.4.3.8.2 Floor mats

Floor mats are available in a variety of types and styles ranging from soft dissipative mats to hard conductive mats. Their portability and ease of use provide for customization and flexibility of work space design, particularly when ESD control requires protection in limited areas. Easy replacement of mats allows their use around wave solder machines or other equipment where major chemical spillage can damage many floor materials. However, mats tend to curl, create tripping hazards and complicate floor maintenance. They are also expensive if ESD control flooring is required throughout a complete area. Their applicability in clean rooms is limited due to contamination of the clean environment. Additional attention is required to ensure a mat is continuously connected to ground.

5.3.3.4.3.8.3 Floor finishes

Static-limiting floor finishes may be applied to a variety of non-ESD control floors: standard vinyl, rubber, or vinyl composition tile, or existing ESD control flooring, to reduce the generation of electrostatic charges. As a floor finish, they protect and they improve the appearance of the floor, and make floor maintenance easier. Floor finishes have flexibility of use, can be applied throughout a facility, and can provide whole area protection. These materials also have some disadvantages:

- Some surfactant type finishes may be too slippery and pose a hazard to employees.
- Some finishes are subject to being washed off with ordinary water. Some finishes can be worn away readily and they may require additional, frequent monitoring to make sure that the finish is still working.
- Improper application and maintenance may cause inconsistent performance of the finish. Some floor finishes may be incompatible with clean room requirements.

5.3.3.4.3.8.4 Topical anti-stats

Topical anti-stats are similar in function to floor finishes, but do not provide physical protection to the floor material itself. They can also be used on carpet. Topical anti-stats are relatively easy to apply; however, they lack permanency and durability.

5.3.3.4.3.8.5 Paints and coatings

Paints and epoxy coatings are applied to concrete floors in thin coats. The primary advantages of these materials are their ease of application and coverage over a wide area.

They have a longer usable life than do floor finishes, but less than permanent floor materials. Paints and coatings tend to wear off in time and should be reapplied on a continuous basis. Some materials are not applicable for clean rooms because they abrade or chip away or are highly loaded with carbon.

5.3.3.4.3.9 Testing

5.3.3.4.3.9.1 General requirements for testing

The standard for testing the electrical resistance of floor materials is IEC 61340-4-1. The test method is designed to operate in the range of 1,0 x 10^4 Ω to 1,0 x 10^{13} Ω. IEC 61340-5-1 requires that the maximum test voltage used for flooring systems used as part of an ESD control program does not exceed 100 V.

5.3.3.4.3.9.2 Product qualification

For product qualification test, floor material samples are evaluated under laboratory conditions where humidity, temperature, and resistance meter test voltages are controlled. Resistance is measured at test voltages of 10 V and 100 V at low humidity.

5.3.3.4.3.9.3 Initial installation or acceptance

When first installed, the floor materials should be tested to make certain that they are functional and meet specifications. Typically, the resistance from the top of the floor material to ground is measured to ensure that the floor material has been properly installed. Verifying that the floor material is connected to ground should be done before ESD sensitive devices are handled.

5.3.3.4.3.9.4 Compliance verification

Compliance verification testing of floor materials is necessary to ensure that they continue to meet specifications. Resistance-to-ground measurements are typically used to verify that the path to ground is intact. In cases where the resistance to ground measurement exceeds the established resistance limits, the following steps can be taken to identify the cause of the high resistance readings:

- Verify visually (if possible) that the floor material is connected to ground.
- Clean the resistance measuring electrode.
- Clean the surface of the floor material. Sometimes a dirty surface can cause the resistance to exceed acceptable limits. Once the surface has been cleaned and allowed to dry if a liquid cleaner is used, repeat the measurement. If the second measurement is within specification this might lead to a further investigation concerning the cleaning practices used by the organization.

The frequency of periodic testing is normally specified in the ESD control program plan/compliance verification plan. However, a common guide would be to conduct these measurements at least once every three months.

5.3.3.4.3.10 Maintenance

Periodic cleaning, following the manufacturer's recommendations, is required to maintain proper electrical function of all floor materials. Ensure that the cleaning products used do not leave an electrically insulating residue which is common to many commercial floor polishes. Ageing of flooring material depends on type, usage and maintenance and is difficult to assess.

5.3.3.4.4 Footwear

5.3.3.4.4.1 Introductory remarks

The routine movement of people, particularly the interaction between shoe and floor while working in a standing position and/or walking, generates charges that can result in human body voltage as high as several thousand volts.

Subclause 5.3.3.4.4 covers the role of footwear (shoes, foot grounders and other devices) in helping control personnel charge accumulation. Subclause 5.3.3.4.4 is intended to provide a description of ESD control footwear and its proper application in conjunction with other ESD control mechanisms. Suggestions for testing and evaluating footwear for use in ESD protective environments are included. Considerations in subclause 5.3.3.4.4 are restricted to factors relating to ESD control. It may be necessary to also consider other factors such as safety issues.

The wrist strap is the first line of defence in personnel grounding. Many manufacturing operations are inhibited and production processes slowed by the use of wrist straps. Mobile personnel can be difficult or inconvenient to ground, with a wrist strap. In these cases wearing ESD control footwear on ESD control flooring can provide an alternative grounding method.

There is a wide variety of footwear grounding devices available. Selection of the appropriate device needs to be based on ESD control requirements, organizations safety requirements, and cost effectiveness. Just as there are many choices in footwear, there are also many choices in ESD control flooring and floor treatments. It is important to consider floor, footwear and individual as three distinct components functioning as a complete system.

5.3.3.4.4.2 Types of footwear

5.3.3.4.4.2.1 Factors influencing choice of footwear

The type of footwear that is used may be influenced by the following: facilities, gender, physical make-up and cultural profiles of personnel, visitors, job descriptions, and budget. It is entirely possible that multiple types of footwear will be incorporated into an ESD control program.

5.3.3.4.4.2.2 Heel and toe grounders

Heel and toe grounders are used for employees and visitors in an ESD controlled area. Heel and toe grounders should be worn on each foot. If worn improperly, heel and toe grounders become ineffective. Heel grounders can easily lose contact with the floor and therefore, may require more monitoring than other types of footwear. It is important that the conductive ribbon has good electrical contact with the person's body through direct contact with the person's skin or by connection through the person's socks.

5.3.3.4.4.2.3 Booties and shoe covers

Booties and shoe covers are often used in environments where particle control and contamination are concerns. Because the connection to the body is generally accomplished by a conductive strip similar to the heel grounder and toe grounder, booties and shoe covers also may be worn improperly. If the bootie is too large, it can slide or move around on the shoe resulting in a loss of continuity with ground.

5.3.3.4.4.2.4 Shoes

If ESD control shoes are chosen, special care should be taken to ensure proper fit. Shoe construction is important. Shoes designed specifically for ESD control purposes should be used. Because many ESD control shoes look like ordinary shoes, a visible tag or marking on the shoe will assist in the monitoring and auditing process.

5.3.3.4.4.3 Proper usage

ESD control footwear is designed to reduce body charge levels by supplying a conductive path from the body to the floor material.

Heel or toe grounders should be worn on both feet to ensure effective use. Care should be taken to evaluate not only the footwear, but also the footwear-flooring combination (see IEC 61340-4-5). Once an upper limit of acceptable body voltage has been determined, typically 100 V, testing should be carried out to ensure that the combination of footwear and floor material performs within the chosen parameters under worst case environmental conditions.

The ability of footwear to remove a charge from a person who moves from an unprotected area to a protected one, or moves about on an ESD control floor, should be evaluated. As a person contacts an ESD control floor material with ESD control footwear, the body charge should dissipate within a few seconds.

5.3.3.4.4.4 Testing

5.3.3.4.4.4.1 General requirements for testing

Footwear testing should include an initial product qualification test, preferably laboratory testing under controlled conditions (see IEC 61340-4-3). Once products are found to meet the existing standards, a system test of the footwear in combination with the existing or proposed floor materials in the plant should be made to ensure that the criteria for the facility are met. Incoming inspection on a lot sampling basis should be performed for all ESD control footwear.

IEC 61340-4-3 is used for evaluating ESD control footwear. The test method describes procedures for initial laboratory evaluations as well as acceptance testing.

IEC 61340-4-5 was developed for measuring the system resistance of the person, footwear and flooring combination as well as chargeability testing of people walking on ESD control flooring while wearing ESD control footwear.

5.3.3.4.4.4.2 Common testing problems

Often, testers used for in-plant monitoring indicate only that the resistance of the system is between two set points. Many testers, such as wrist strap testers, do not have set points to accommodate the actual resistance ranges of ESD control footwear. The recommended approach is to use a tester designed specifically for footwear.

Occasionally, footwear may indicate a high resistance. Outside of the shoe material itself being a contributor to high resistance, the wearer’s skin (if dry), thick insulating socks, the absence of a sweat layer due to differences in temperature between the inner surfaces of the shoes and the wearer’s feet or contaminants such as wax build up from office area flooring can cause the resistance to exceed acceptable levels.

5.3.3.4.5 ESD control seating

5.3.3.4.5.1 Introductory remarks

A common source of static electricity in the workplace is the movement of people and materials. The routine movement of a person seated in a chair or movement of the chair itself across the floor can generate significant voltages. Subclause 5.3.3.4.5 covers the use of seating in an ESD protected area for dissipation of charge. Although not recommended in IEC 61340-5-1 as a means of grounding personnel in the workplace, the use of chairs that meet resistive requirements from the seat contact surface to the castors or chair legs, may be an effective means of grounding personnel if a reliable method can be found to create sufficient bonding of the person and the chair. This situation is one possible example of tailoring. The required values of the system resistance from person to ground and maximum resistance of chairs, needs to be determined and documented in the tailoring statement. The potential of the person needs to be reliably maintained below the body voltage required by the ESD control program. Continual contact should be ensured between all the elements in the system including the person, the chair and the ESD control flooring surface.

5.3.3.4.5.2 Relationship between chairs, flooring and the user

ESD control seating dissipates charge from the user by providing a conductive path from the portion of the body that is in contact with the chair to the flooring material on which the chair rests. Much like the footwear-flooring combination, the chair may rely on a sweat layer between the user and the seat cushion in order to be effective. Because the chair has more mechanical parts, a variety of constituent materials and several connection points between these materials and parts, it is not relied on as heavily as the wrist strap or flooring/footwear combination in grounding personnel. Yet, if tested to resistance specifications, these interfaces can be checked to ensure that grounding is achieved. As with footwear, seating is not effective unless used in conjunction with a static protective floor.

5.3.3.4.5.3 Benefits

There are some benefits associated with the use of static protective seating. Standard chairs, particularly those with plastic castors may induce significant voltage levels on the user if they are not wearing a wrist strap in areas without protective flooring and footwear. Seating whose wheels, structure and cushions are adequately bonded between each other and which possess adequate resistance properties may help to reduce these voltages to safe levels. However, in the absence of a ground connection via the flooring, seating should not be relied on to keep body voltages below the required limit.

5.3.3.4.5.4 Types and selection

Seating comes in various styles; desk height chairs, bench height chairs, stools and sit/stands. ESD control seating surfaces that contact the body (including arm, foot and backrest) should be capable of dissipating charge from all surfaces of the seating through the components of the chair/stool to ground. Fabric upholstered chairs accomplish this by using conductive fibres woven into the fabric. The fabric is then connected through the components of the chair, through the cylinder, base and casters (or drag chain) to the floor.

Some environments, such as clean rooms, require the use of vinyl upholstery in place of fabric. ESD vinyl upholstery is manufactured with a thin conductive layer below the surface of the vinyl. Vinyl upholstered chairs may have a slightly higher resistance measurement than fabric chairs; however, they should still meet the resistance requirements listed in IEC 61340-5-1.

5.3.3.4.5.5 Testing

A procedure that can be used for testing the electrical resistance of seating can be found in IEC 61340-2-3. Use the general test method described for making resistance to ground or groundable point measurements. The seating surfaces to the chair’s groundable point (caster or drag chain) should be evaluated.

When used as part of an ESD control program, the required electrical resistance range for seating is less than 1,0 x 10^9 Ω as tested in accordance with the requirements established in IEC 61340-5-1. This value applies to laboratory evaluations, acceptance testing and periodic testing.

5.3.3.4.6 Ionization

5.3.3.4.6.1 Introductory remarks

The primary method of static charge control is direct connection to ground for conductors, static dissipative materials and personnel. However, a complete ESD control program should also deal with isolated conductors that cannot be grounded as well as insulating materials (e.g., most common plastics). Humidity and chemical sprays may be used to dissipate static charges from these items under some circumstances. However, humidity is a slow method of dissipating static charge, and chemical sprays are not applicable in environments such as clean rooms.

Air ionization can neutralize the static charge on insulated and isolated objects by charging the molecules of the gases of the surrounding air. Whatever static charge is present on objects in the work environment, this will be neutralized by attracting opposite polarity charges from the air. Because it uses only the air that is already present in the work environment, air ionization may be employed even in clean rooms where chemical sprays and some static dissipative materials are not usable.

Air ionization is not a replacement for grounding methods. It is one component of a complete ESD control program. Ionizers are used when it is not possible to properly ground everything and as backup to other ESD control methods. In clean rooms, air ionization may be one of the few methods of ESD control available.

IEC 61340-4-7 defines test methods and procedures for evaluating the performance of air ionization equipment. Included in the standard are three annexes that briefly discuss the processes of air ionization and charge neutralization, design of the charged plate monitor (the recommended measuring instrument) and other issues related to the use and testing of ionizers.

The purpose of Subclause 5.3.3.4.6 is to supplement the information presented in the standard test method in IEC 61340-4-7. It discusses how ionizers operate, how their electrical performance is measured, the major types of ionizers and their use environments, important elements of a performance specification, testing methods, safety, maintenance, and contamination issues.

5.3.3.4.6.2 Contamination control

Another application of air ionization is to improve contamination control.

Balanced air ionization can enhance the ability of the air filtration system to remove particles from the clean room environment. Ionization neutralizes charges on critical surfaces and reduces the attraction of particles to these surfaces. Particles have a greater tendency to remain in the laminar airflow and then be removed by the air filtration system.

5.3.3.4.6.3 What is air ionization?

Air ions are molecular clusters of about 10 molecules (often water) around a charged oxygen or nitrogen molecule. The ion may have a positive charge (deficiency of electrons) or a negative charge (excess of electrons). The natural concentration of ions in air is low, typically less than 1 000 per cubic centimetre. These "natural" ions are usually formed during the decay of natural radioactive elements in the air, in the ground or in building materials.

For neutralization purposes higher ion concentrations are needed. Radioactive sources, usually polonium 210, may be used under certain conditions to produce air ions. Alpha particles emitted by nuclear ionizers are positively charged helium nuclei (two protons, two neutrons and no electrons). When these alpha particles collide with molecules in the air, they displace electrons from some air molecules (creating positive air ions). These "free" electrons are eventually captured by other air molecules (creating negative air ions). See Figure 6.

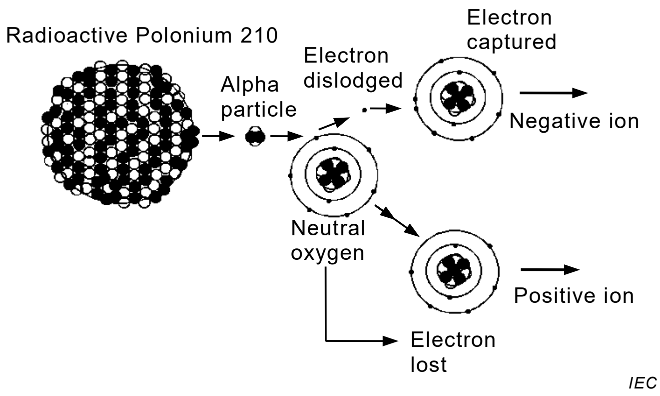


Figure 6 – Ionization by alpha radiation

In other situations, the most common ion production method is by interaction between neutral air molecules and electrons accelerated in an electric field with field strengths exceeding 3 MV/m (at atmospheric pressure). This is generally referred to as high-voltage corona ionization or corona discharge (see Figures 7 and 8).

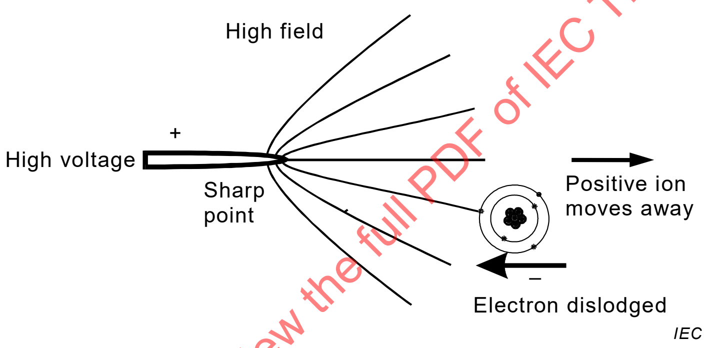


Figure 7 – Corona ionization – Positive

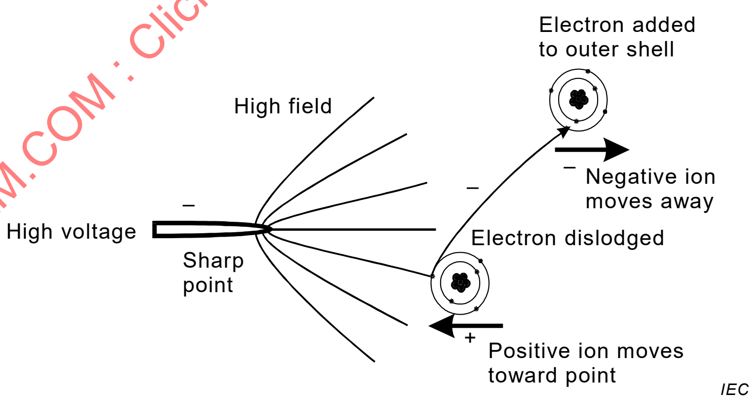


Figure 8 – Corona ionization – Negative

5.3.3.4.6.4 Measurement of air ionization

If an ion is exposed to an electric field, it will move at a rate dependent on the magnitude of the electric field, and in a direction dependent on the direction of the electric field and the polarity of the ion (either may be positive or negative). The motion of ions in an electric field is an electric current whose current density will be dependent on the number of the ions in the air and the rate at which the ions move away from or towards the source of the electric field.

If an object is charged, an electric field is established around the object. The field strength will vary from point to point, but is always proportional to the charge. If the object is surrounded by ionized air of both polarities, a current will flow towards the object carried by the ions of polarity opposite to its charge. This "neutralization current" is proportional to the charge on the object and to the amount of ions available in the surrounding air (ion density). For examples of corona ionization, see Figure 7 and Figure 8.

If the ion density does not change, the relative rate of charge neutralization is constant and the charge will decay exponentially with a time constant that depends on the ion density. In practical situations it is difficult to maintain this condition. Particle concentrations in the air, depletion of ions in the vicinity of the charged object, non-homogeneity of the ionized air, and non-uniform fields due to nearby objects will all cause variations in the rate of charge decay. Making corrections for all deviations from the simple case to calculate the time constant is impractical. It is more reasonable to measure the neutralizing properties of an ionizer experimentally using a charged plate monitor.

5.3.3.4.6.5 Charged plate monitor (CPM)

The charged plate monitor is used to measure the neutralizing properties of an ionizer or ionizing installation. The charged plate monitor consists of an isolated conductive plate, which may be charged to a fixed initial voltage by a suitable external device. The voltage of the plate is monitored either by coupling it to an electrometer or by measuring the field from the plate using a non-contacting field meter.

If the charged plate monitor is placed in an ionized environment, the rate of charge neutralization by the ionizer may be characterized by the discharge time. This has been defined as the time it takes for the plate voltage to drop from its initial value to 10 % of its initial value (for example 1 000 V to 100 V). The ionizer balance may be determined by momentarily grounding the isolated plate, and then noting any voltage induced on the plate by the ionizer operation. This voltage is known as the offset voltage. Detailed information on the charged plate monitor and the measurement technique are contained in IEC 61340-4-7.

5.3.3.4.6.6 Purpose of ionization

Selecting an ionizer to solve a static problem will often involve a number of considerations besides the ability of the ionizer to neutralize a static charge. In general, ionization should be engineered for a particular application, and then evaluated in the actual area it will be used.

It should be remembered that air ionization is installed because there is a static problem. In most cases the air ionization is installed to neutralize static charges on process-essential insulators and isolated conductors. Often, these insulators and isolated conductors are part of the product being manufactured. Ionization, working alone or in addition to passive ESD control methods, should demonstrate that it can reduce or eliminate the static problem. There are many different technologies and types of equipment for making air ions. There is no best ionizer for all applications. But, by carefully understanding the requirements of one's own application, it may be possible to determine the best ionizer for that specific application.

5.3.3.4.6.7 Types, use, selection and installation of air ionizers

5.3.3.4.6.7.1 Types of air ionizers

Two primary methods of producing air ionization are nuclear decay by alpha emission, and corona discharge caused by high electric fields. Corona discharge ionizers come in a variety of types, the most common being AC ionizers, steady-state DC ionizers, and pulsed DC ionizers. Also available are X-ray ionizers that use soft X-ray sources to produce air ionization.

NOTE Corona discharge air ions are created when a high voltage (AC, DC) is applied to a point or emitter.

5.3.3.4.6.7.2 Nuclear ionizers

Nuclear ionizers commonly use polonium 210 as the radioactive element for producing air ionization. The nuclear material is packaged in a way that prevents its release from the ionizer, but still allows alpha particle emission to ionize the surrounding air. The alpha particles collide with gas molecules in the air, displacing electrons. When electrons are displaced positive ions are produced. When the displaced electrons are captured by neutral gas molecules, negative ions result. Nuclear ionizers do not produce an electric field. They should be used in close proximity to the charged surface, or depend on airflow to disperse the air ions into the work area. Figure 7 illustrates the radioactive event.

5.3.3.4.6.7.3 AC ionizers

AC systems utilize emitters that are switched rapidly between positive and negative high voltage, usually at the power line frequency. Ion recombination is high, as both polarities are produced in rapid succession at each emitter point. The electrostatic field from the emitter points also changes direction rapidly. In some situations, it may not be desirable to place sensitive components close to the emitter points. For these applications, moving ions away from the emitter points will require airflow. AC systems are often mounted at the output of an air delivery system.

5.3.3.4.6.7.4 Steady-state DC ionizers

Steady-state DC systems consist of separate negative and positive ion emitters connected by a pair of high voltage cables to their respective high voltage power supplies. The spacing between emitters will vary depending on the design, and DC power is constantly applied to the emitter points.

Emitters of opposite polarities are spaced farther apart in the DC systems than in the AC systems. Ion recombination occurs at a lower rate and steady state DC systems will operate at a lower airflow than AC systems. In some situations, it may not be desirable to place sensitive components close to the emitter points. The electric field of the ionizer is used to move ions in the absence of high airflow. Care should be taken that the emitters are not spaced so far apart that ion hot spots are created. Ion hot spots contain an oversupply of ions of one polarity and any objects brought into these areas may be charged by this ion imbalance.

5.3.3.4.6.7.5 Pulsed DC ionizers

Pulsed DC systems generate both polarities of ions at a single emitter unit using a single or closely spaced pairs of emitter points. Power distribution may be by high-voltage cables from a central high-voltage power supply, or by low-voltage cable from a central controler to remotely located high-voltage power supplies. By alternating relatively slowly between polarities (usually at a pulse rate of 10 Hz or less), the recombination rate is lowered; however, offset voltage cycling does occur. Generating both polarities at a single location eliminates ion hot spots and allows the electric fields to move ions in low airflow applications. In some situations, it may not be desirable to place sensitive components close to the emitter points. By varying the pulse rate, ions can be delivered to the work area, even in “zero” airflow situations.

5.3.3.4.6.7.6 X-ray ionizers

Soft X-ray sources (less than 10 KeV energies) can be used to provide the energy to displace electrons from the gas molecules in the air. When electrons are displaced, positive ions are produced. When the displaced electrons are captured by neutral gas molecules, negative ions result. X-ray ionizers produce ions along the path of the X-ray, which may be up to 1 m or more in air. X-ray sources should be shielded to prevent exposure to personnel. There is no electric field, but ions are produced in a volume of air, without airflow being required.

5.3.3.4.6.8 Environments for using air ionizers

Nuclear, corona and soft X-ray ionizers are available in a number of different types. The choice of an ionizer often depends on the size or type of area in which it will be used. Products are available that provide ionized air for entire rooms, laminar airflow benches, work surfaces, specific points of use, compressed gas lines, and a variety of custom applications which are beyond the scope of this document.

5.3.3.4.6.9 Room ionization

Room ionization devices are used when static problems occur over a wide production area and it is difficult to localize the problem to a particular workstation. Room ionization devices include AC powered grid systems, spaced pairs of steady DC emitters, steady DC bar systems, pulsed DC bar systems, and individual pulsed DC emitters. Nuclear ionizers are not commonly used in room systems because of the quantity of radioactive material that would be required.

Regardless of the type of room ionizer chosen, a number of environmental and equipment issues should be addressed when large areas are to be ionized. Consideration should be given to the ceiling height and airflow present in the area. Any large objects in the area will change both the airflow and the operation of the ionizers. Methods of power distribution to the ionizers as well as other installation requirements need to be considered. After installation, these large systems will require periodic maintenance to ensure the desired performance. In contrast to other ionizer applications, room ionization often involves an engineered system, rather than an off-the-shelf product.

5.3.3.4.6.10 Laminar flow bench ionization

Laminar airflow benches are in common use in the electronics industry and in many other applications. They are used to create a contamination controlled workstation within a larger uncontrolled production area. Within the area of these laminar airflow benches, static charge can cause both ESD and particle contamination problems. AC grids, steady DC, pulsed DC bars and nuclear bars are used to provide ionization in laminar airflow benches. The level and direction of the airflow available in these benches may affect the type of ionizer chosen. Any large objects in the bench area will affect both the airflow and the operation of the ionizer. Power distribution may need to be considered if large numbers of electrical ionizers are to be used. As with all ionizers, periodic maintenance will be needed to provide optimum ionization capabilities.

5.3.3.4.6.11 Worksurface ionization

The type of ionizer used to provide ESD control on any work surface depends to a large extent on the area in which the worksurface is located and the amount of airflow available. In contamination-controlled areas, and other areas with significant amounts of airflow, the products described under room ionization, or laminar flow bench ionization, may be usable. In areas where there is little ambient airflow, other types of ionizers may be used. These are commonly known as bench top blowers or overhead workstation ionizers, and include fans in their design. They may use nuclear or any of the previously described types of corona ionization technology.

5.3.3.4.6.12 Point-of-use ionization

There is sometimes a need to provide ESD control in a small defined area or location. This may be done to provide ESD control within production equipment, in mini-environments or to facilitate particle removal from part of a product. Ionizers used for this purpose may be blow-off guns or nozzles that work with a supply of compressed air or nitrogen. They may use either nuclear, soft X-ray or any of the previously described types of corona ionization technology. It will be important to choose a method of ionization and cleanliness of the gas supply that is appropriate to the work area.

5.3.3.4.6.13 Selection of air ionization equipment

5.3.3.4.6.13.1 Establishing performance specifications

Selecting an air ionizer for a specific application often involves deciding between a number of different variables. There are a wide variety of problems caused by static charge, and a wide variety of products affected by these problems. When a specification is established, it should take into account the nature of the static problem, the sensitivity of the product to static charge, the environment in which the ionizer will be used, and the operating characteristics of the ionization equipment. Some of the issues to be considered are shown in Table 2.

Table 2 – Ionizer selection checklist

Charge neutralization	Operation
1. Discharge time	1. Maintenance requirements
2. Balance (offset voltage)	2. Reliability
3. Product sensitivity	3. Equipment service
4. Solution to static problem	4. Ozone, EMI and particle emissions
Environmental considerations	**Cost**
1. Airflow	1. Equipment cost
2. Physical dimensions	2. Installation cost
	3. Operating and maintenance costs
Installation considerations	
1. Conformity with safety codes	
2. Power distribution	
3. Power control	
4. Compressed gas needs	
5. Expansion capability	
6. Cleanroom compatibility	

Evaluating an ionizer in the actual area of use is the preferred practice. This will provide data on ESD control performance, the effect of ionization on the static problem, and demonstrate other ionizer device features which may be important to the selection process.

Choosing an air ionizer to solve a static charge problem often requires compromises between conflicting equipment and performance requirements. Often an evaluation system installed in your actual area is the only way to determine the functionality and effectiveness, to analyse other equipment evaluation criteria and consider installation techniques and determine maintenance issues.

5.3.3.4.6.13.2 Defining the static problem

An air ionizer that is used to protect against ESD in an assembly area, may be different from an ionizer that reduces particle contamination on wafer surfaces in an ISO Class 3 clean room. The first step in writing a specification is to understand the static charge problem that needs to be solved. It is important to define the nature of the problem so that you can demonstrate later in your evaluation of ionizers that the problem has been solved.

5.3.3.4.6.13.3 Discharge time and offset voltage

A performance specification depends on the sensitivity of the product to the effects of static charge and the rate at which charge should be neutralized to eliminate the static problem. First, determine the amount of static charge that will cause product damage. A variety of test methods are available to provide this information. Product damage thresholds may determine the allowable offset voltage, or balance, of the ionizer. Offset voltage measured with the charged plate monitor may be part of the performance specification.

Static problems are usually two step events. Static charge is created and then at some later time, it causes a problem. If nothing is done to neutralize the static charge, it may remain for hours, depending on the ambient humidity. Using an ionizer, it may be possible to neutralize the static charge as quickly as a few seconds, or as long as a few minutes. As discharge time depends very strongly on the available airflow, the desired discharge time may not be achievable under all circumstances. Compromises will usually have to be made between discharge times, offset voltage and available airflow. In each application of an ionizer, the user will have to determine if the static neutralization capabilities are sufficient to solve the static problem.

5.3.3.4.6.13.4 Other selection issues

Depending on the application, there may be additional issues that need to be addressed. All ionizers will need some type of maintenance or periodic certification and this may need to be a part of the performance specification. Since most ionizers operate continuously, there may be significant demands for equipment reliability. Operation in clean rooms or other sensitive areas may require attention to the issues of ozone, EMI and particle emissions.

5.3.3.4.6.13.5 Cost considerations

System cost is an obvious criterion for selection. A thorough cost/benefit analysis should be performed. This analysis should include initial purchase cost, as well as installation, maintenance and replacement cost over a defined period. These costs should be weighed against the benefits such as improved yields/throughput and improved quality.

Along with the initial system cost, the operating cost of electrical power and in some instances (nozzles and blow-off guns) the cost of compressed air should be considered. Other items to consider are the cost of required maintenance and calibration. These costs will be affected by their level of complexity and frequency required.

5.3.3.4.6.14 Installation of air ionization equipment

5.3.3.4.6.14.1 General installation considerations

The installation of ionizers should conform to applicable electrical, mechanical, and safety codes, as well as individual facility standards. Electrical power distribution, cabling, mounting methods, and materials need to be appropriate. Contamination controlled areas often require specialized installation techniques and materials. Installation methods should consider possible future changes in the work area as well as present needs. The installation of electrical ionizers should comply with all local and national electric codes.

Power should be supplied to most ionizers. Some ionizers use a separate power supply transformer connected to line voltage power. Larger ionization systems distribute power from a central controler to the individual ion emitters. Two primary methods of power distribution are used from these power sources to the ion emitters. Low-voltage power distribution uses voltages of 60 V AC/DC or less. High-voltage power distribution uses voltages up to 7 000 V AC or 20 000 V DC. In high-voltage power distribution, insulation should be suitable for the applied voltages and particular care should be exercised in cable routing. Sharp edges should be avoided or supplemental insulation should be added at these points to avoid premature cable failure.

Make sure that mounting methods are compatible with safety codes and facility requirements. Some ionizers will need a source of compressed gas whose cleanliness is compatible with the area in which the ionizer will be used.

Ionizers may be installed at the time a facility is built. Most often, however, ionizers are installed after the facility is in operation and static problems need to be solved. Any installation of ionizers in an operating production environment should not interfere with ongoing production. The cost of a production shutdown can be many times more expensive than the cost of the ionizer. Also, if installation is to be carried out in a clean room environment, it should not compromise the integrity of the clean room.

5.3.3.4.6.14.2 Airflow considerations

The performance of an air ionizer often depends on the amount of air that flows by or through the device. Some ionizers require airflow to operate correctly, while others do not. Some will use the existing airflow, while others include fans in the product design. Still others use clean, dry compressed gases such as air or nitrogen.

Performance requirements for the ionizer should take into account the type and amount of airflow available. It is not reasonable to expect the same performance from an ionizer in both the turbulent airflow of an assembly area and in the 30 m/min laminar airflow of a clean room. In applications with inadequate airflow, fans may be used for distributing air ions. Determine if these fans are compatible with the cleanliness of the work environment. If not, the performance of an ionizer that operates with the existing airflow may have to be accepted. Whatever method is used to distribute the ions, there should be no obstructions between the ionizer and the work area.

5.3.3.4.6.14.3 Zoning and flexibility to change

The need to control the ionizers varies depending on the application. Less critical situations may be satisfied by factory control settings or adjustment of a large ionized area by a single central controler. More critical applications may require adjustability to be part of the performance specification. Small control zones may be required, or even the ability to fine-tune the ion output at each individual ion emitter point. Some devices, such as nuclear ionizers and X-ray ionizers are intrinsically balanced and provide no adjustment of their operation.

In most production facilities the equipment layout rarely remains the same for long periods of time. It is important to determine the flexibility to change or expand the ionizer installation at a later date. Minor changes should be possible using in-house personnel, and expansion capacity should be part of the original equipment specification. Change or expansion should be possible without costly production shutdowns.

5.3.3.4.6.14.4 Monitoring and feedback control

Various feedback and auto-balance methods are available to ensure ionizer performance. But make sure that enough sensors are included to provide adequate monitoring information to the control system. Most ion sensors have a limited range, usually less than 1,5 m. Unless you can guarantee uniform conditions throughout a large area, many ion sensors may be needed to monitor large installations. Providing a sensor for each ionizing device can improve feedback control. Also, an effective monitoring and control method can reduce the amount of maintenance required for proper operation of the ionizer device or system.

5.3.3.4.6.15 Testing of air ionizers

5.3.3.4.6.15.1 Selection testing

A complete evaluation of ionizer performance should answer two basic questions. First, are ions arriving in the work area in the proper quantity and balance to neutralize static charges? Second, and more important, does ionization reduce or eliminate the problem caused by the static charge? The static discharge performance of all air ionization devices should be evaluated using the existing industry standard IEC 61340-4-7. Any evaluation should also include testing that is specific to the actual problem to be solved. The user should have to identify the static problem, establish a realistic performance specification, select from among the different types of ionizers and test the ionizers in the actual location where they will be used. IEC 61340-4-7 provides guidelines for testing the discharge performance and balance of ionizers. These guidelines may need to be modified to meet the physical requirements of the specific installation.

Once it has been established that ionizers will solve a static problem, a set of tests should be created for qualification and acceptance of ionizers. These tests should demonstrate that the ionizer will satisfy the performance specification for the intended use. The acceptance testing should be simple enough to be performed by the user's incoming inspection personnel, or by personnel upon initial installation of the equipment.

Often the test methods and guidelines of IEC 61340-4-7 are used to perform this qualification and acceptance testing of ionizers. A standardized test fixture or test area may be constructed to ensure that all ionizers are tested under repeatable, equal conditions. The user determines how accurately measurements in this test fixture or test area should correlate with performance in the actual area the ionizer is used. If more than one type of ionizer is to be qualified for use or if different types of areas are to be ionized, multiple test fixtures may be required. Sometimes, ionizers will be tested only after they have been installed in the use location. Acceptance testing standards should then be a part of the purchasing process.

Testing should be carried out using the charged plate monitor (CPM) and the methods of IEC 61340-4-7. Ionizer performance should be compared to the performance requirements developed by the user for each specific application. Using industry standard tests ensures that ionizers will be compared on an equal basis, even though the requirements of each application will differ. It has been noted that there is a great variation in the discharge performance and the offset voltage balance required from ionizers. In some cases a small non-standard CPM may be used for evaluation. The performance of the smaller CPM should be verified against the standard CPM.

For some applications of ionization, particularly point-of-use ionization, it may be difficult to use a CPM, due to physical size constraints. When this problem is encountered, it may be necessary to develop an alternative test methodology. One method uses an electrostatic field meter to measure the charge on product or equipment, before and after using ionization. Alternatively, a non-conductor may be charged by rubbing it against another material, or an isolated conductor may be charged by momentarily connecting it to a voltage source. Monitoring these materials with the electrostatic field meter will demonstrate the ability of the ionizer to reduce static charge.

5.3.3.4.6.15.2 Confirmation of process improvement

Testing specific to the application should then demonstrate that the presence of an ionizer has solved the static problem. The problem may be ESD damage, particle deposition on product surfaces or production line downtime. Whatever the problem, testing should verify that it is reduced or eliminated by using an air ionizer. In some cases, it will be necessary to carry out yield studies of all or part of the manufacturing process.

5.3.3.4.6.15.3 Periodic verification testing

Once ionizers have been installed, it is desirable to measure their performance. This provides a baseline against which to monitor their long term operation. The test methods and guidelines of IEC 61340-4-7 may be used to perform this periodic verification testing of ionizers.

Ionizers should be tested for discharge time and balance after they have been installed in the use location. A certification document detailing the test conditions and test locations should be generated at that time. The time intervals for subsequent measurements will depend on the user requirements. Less critical applications may require only appropriate maintenance and annual performance checks. More critical uses may demand maintenance schedules and semi-annual or quarterly recertification. Users should be very aware of the costs and responsibilities involved.

5.3.3.4.6.16 Maintenance and cleaning

5.3.3.4.6.16.1 General considerations for mantanence and cleaning

5.3.3.4.6.16.1.1 Introductory remarks

All ionization devices will require periodic maintenance for proper operation. Maintenance intervals for ionizers vary widely depending on the type of ionization equipment and use environment. Critical clean room use will generally require more frequent attention. It is important to set up a routine schedule for ionizer service. Routine service is typically required to meet quality compliance verification requirements.

5.3.3.4.6.16.1.2 Corona (electrical) ionizers

With electrical ionizers the emitter points should be cleaned regularly and may have to be replaced periodically. Balance and discharge time should be checked at scheduled intervals using a charged plate monitor. Some electrical ionizers will require adjustment of the ion balance at this time. The typical sequence is to clean the unit, including emitter points, set ion balance to zero (if adjustable) and then perform discharge time testing. If the unit does not meet ion balance specifications or minimum established discharge time limits, further service is indicated. Manufacturers should provide details on service procedures and typical service intervals.

5.3.3.4.6.16.1.3 Nuclear ionizers

Nuclear ionizers do not use emitter points, but they typically require annual leak testing by the manufacturer. Although the ionizing element has a predictable life expectancy, routine ion balance and discharge time testing should be performed to ensure that the unit is functioning properly. The ionizing element is usually returned to the manufacturer for replacement and disposal.

5.3.3.4.6.16.1.4 X-ray ionizers

X-ray ionizers do not use emitter points, but eventually the X-ray tube will need to be replaced. The ionizer is normally returned to the manufacturer for this service to be performed. Routine ion balance and discharge time testing should be performed to ensure that the unit is functioning properly.

Manufacturers can provide assistance in specifying the appropriate calibration and maintenance required. If these services are needed on a contract basis, make sure they are available from the manufacturer or an approved service agency of the ionization devices under consideration.

5.3.3.4.6.17 Environmental and humidity ionization considerations

In general, most air ionizers are designed to work in typical factory environments within temperature and humidity limits specified by the ionizer manufacturer. Condensing humidity, contamination with bases and acids or topical sprays will often create problems with the operation of electrical ionizers. Electrical ionizers typically use high voltage, low current for ionization. If these contaminants settle on high voltage insulation, they render the insulation mildly conductive. This undesired conductivity may allow unwanted currents to flow within the ionizer resulting in improper operation of the ionizing elements.

The manufacturer should be consulted before installing nuclear ionizers in corrosive environments.

Flammable and explosive environments pose risks that are outside the scope of this document. The manufacturer of the ionizing equipment should be consulted for these installations.

5.3.3.4.6.18 Other considerations

5.3.3.4.6.18.1 Safety issues

Electrical ionization involves the use of high voltages applied to a sharp emitter point. Depending on the design of the ionizer and the method of installation, personnel may come into contact with the emitter points. This may occur accidentally or during normal maintenance procedures. Unless ionizers are installed where no contact with the emitter is possible, consideration should be given to preventing electrical shock or physical injury from contact with the emitter points. All ionizers should meet all local and national safety laws.

5.3.3.4.6.18.2 EMI, ozone and particle emissions

There is sometimes a concern about EMI or ozone generation by air ionizers. Manufacturers' data for specifications in these areas should be consulted, but note that test methods and test conditions vary widely. If ionizers are to be used in an area that is sensitive to EMI or ozone, it is strongly recommended that the ionizer be evaluated under normal operating conditions in that area. The ionizer should meet the same standards applied to other equipment used in the area. Sensitive product or equipment should be placed in the ionized area, and the effect of the ionizer on them should be evaluated. Most ionizer manufacturers will provide equipment for this type of testing.

All emitter points require periodic cleaning and replacement, the frequency depending on the material used, the design of the ionizer and the environment in which it is used. There has never been a study linking normal emitter point wear of currently used emitter materials to increased product defects. On the other hand, many studies have shown fewer product defects occur when ionizers are in use.

Ionization devices should meet the same particle emission standards as those that are applied to other production equipment used in clean room areas. If other production equipment is checked for particle emission, use the same test for air ionizers. Although no standards currently exist for measuring particle emission from air ionizers, it is likely that the interest in this issue will cause them to be proposed in the near future.

5.3.3.4.7 Garments

5.3.3.4.7.1 Introductory remarks

In some cases, for example in clean rooms, use of ESD control garments may be clearly indicated as over garments if required from a contamination prevention standpoint. In this application ESD control garments should shield electrostatic fields from under garments and should not themselves be a source of electrostatic fields that may lead to contamination by electrostatic attraction of particles.

In other cases, garments may be required to be worn over, or in place of non-ESD control garments to protect workers from hazards or for other operational reasons. The ESD risks associated with such garments may be higher than with non-ESD control garments, and ESD control may become a requirement.

In other cases, however, it is not possible to state a general requirement for ESD control garments, and ESD coordinators should then use their judgement to determine if the ESD risks associated with everyday clothing or workwear are sufficient to warrant the use of ESD control garments. ESD coordinators may also select ESD control garments because of benefits, for example establishing discipline of ESD control. Some factors that may be taken into account include:

- the ESD withstand voltage of the ESDS being handled (especially for ESDS with low CDM withstand voltage),
- the cost and consequences of an ESD failure,
- the reliability required of the product and its market,

- the type of facility and handling processes,
- clean room and other operational requirements,
- worker protection,
- the climate and environmental conditions of the facility,
- the culture of the facility.

The ESD risks associated with everyday clothing and workwear cannot always be easily assessed. The current general view of experts is that the main source of ESD risk may occur where ESDS can reach high induced voltage due to external fields from the clothing, and subsequently experience a field induced CDM type discharge. So ESD control garments may be of particular benefit where larger ESDS having low CDM withstand voltage are handled, and operators habitually wear everyday clothing or workwear that could generate significant electrostatic fields.

As an example, a facility in a warm humid climate, in which operators habitually wear short sleeve T-shirts and the product has no special ESD susceptibility, may not require ESD control garments. In contrast another facility in a dry climate handling high cost low withstand voltage ESDS in a high reliability application may choose to use ESD control garments, especially if operators wear long sleeved clothing that may generate electrostatic fields. Most facilities, however, will fall somewhere between these extremes and should make their decision based on a technical assessment of their particular conditions.

5.3.3.4.7.2 Types and selection

5.3.3.4.7.2.1 Types of garments

There are several different types of garments available. Areas in which the garments are to be worn and the processes in that area, should be considered as part of the selection criteria for the most suitable garments.

Different textile technologies can be used to make ESD control garments. The following are examples of textile technologies available:

- limited use (disposable);
- re-usable, topically treated;
- re-usable, permanent ESD control properties.

IEC 61340-4-9 defines three types of ESD control garments based on resistance characteristics and whether or not they require grounding:-

- static control garment – a garment that provides ESD control without necessarily being grounded;
- groundable static control garment – a garment that has a designated groundable point and exhibits a low resistance from point-to-point and from any point on the garment to the groundable point;
- groundable static control garment system – a garment that has a designated groundable point and is used to ground the wearer via the garment, typically by means of a ground cord attached to the groundable point.

When selecting the most appropriate type of garments, consideration should be given to the technology used for ESD control, the requirements for maintaining ESD control properties, and any limitations or restrictions with respect to operational practices and worker habits.

5.3.3.4.7.2.2 Limited use (disposable)

The intent is for the garments to be worn a predetermined number of times and then disposed of. If these garments are reused, an auditable tracking system is recommended to monitor the integrity of the garment, which should be documented in the ESD control program plan.

Limited use garments are typically made from non-woven fabrics. Woven or knitted fabrics may also be used, but are less common. ESD control properties are often obtained by the application of topical treatments or finishes that are designed to be effective for a limited period of time or use. In the case of non-woven fabrics, antistatic additives may be used in the formulation of the fibres or coatings.

The use of topical treatments or finishes, or antistatic additives is often the most cost efficient way of making limited use ESD control garments. However, effectiveness is often humidity dependent. Where ESD control is required under low humidity conditions, fabrics that incorporate conductive fibres may be used to make limited use garments. Another option for non-woven fabrics is to use so-called permanent antistatic additives or inherently conductive polymers in the formulation of the fibres or coatings.

Limited use garments are commonly used in areas such as the application of conformal coating where the garments can easily become contaminated and may need to be replaced frequently. They also provide a cost efficient option when the use of ESD control garments is only required on an occasional basis.

5.3.3.4.7.2.3 Re-usable, topically treated

Topically treated garments require treatment during or following each cleaning cycle. They are generally humidity dependent in that the surfactants (surface active agents), treatments or finishes typically used, are hygroscopic and depend on moisture in the air for garments to perform properly as ESD control garments.

In some cases, garments may be made with fabrics containing conductive fibres, but which also require topical treatment. Such fabrics may contain lower quantities of conductive fibres compared to garments with permanent ESD control properties, and hence the cost of manufacture may be lower. The advantage compared to the use of topical treatment alone is that the amount of treatment required may be less, the wear time between treatments may be longer, and ESD control is less dependent on humidity.

5.3.3.4.7.2.4 Re-useable, permanent ESD control properties

Garments with permanent ESD control properties should maintain performance requirements for at least their expected use life. In general, garments that maintain their ESD control properties following 50 or more commercial cleaning (laundry) cycles can be considered to be permanent ESD control garments. These garments are typically constructed from fabrics that have conductive fibres placed in a grid or stripe pattern throughout the garment.

5.3.3.4.7.2.5 Static control garments

Static control garments may be constructed using any of the textile technologies described above.

Some static control garments do not require a specific connection to ground.

In other cases, static control garments that are not grounded may acquire charge on conductive elements that creates a significant ESD risk. Such garments may not meet the requirements for groundable static control garments as defined in IEC 61340-4-9, but nevertheless require grounding in order to eliminate ESD risks. In these cases, it is important that wearers understand how the garments should be grounded according to the manufacturers' instructions.

5.3.3.4.7.2.6 Groundable static control garments

For groundable static control garments, the maximum resistance between any point of the garment and the groundable point of the garment should be less than specified in IEC 61340-5-1. These garments typically have one or more designated groundable points, which will make it possible to ground all panels of the garment through one electrically conductive grounding means such as a ground cord or via footwear and flooring.

Groundable static control garments may be constructed using any of the textile technologies described above, with some limitations. Topical treatments and non-permanent antistatic additives may degrade in a non-uniform way, such that electrical continuity to groundable points becomes compromised even though large areas of fabric may retain their original properties. Continuous monitoring may not necessarily detect this.

In general, fabrics incorporating core conductive fibres cannot be used to make groundable static control garments, unless a topical treatment is also used.

Fabrics that incorporate conductive fibres in stripe patterns will either require topical treatments, or the inclusion of additional conductive material in the seams between panels to maintain electrical continuity in groundable static control garments.

Fabrics that incorporate surface conductive fibres in grid patterns may be used to construct groundable static control garments with the most reliable performance, particularly if additional conductive material is included in the seams between panels.

After verifying that the garment has electrical continuity through all panels, the garment should be electrically bonded to the grounding system of the wearer so as not to act as a floating conductor. This can be accomplished either by:

- grounding the garment through a conductive wrist cuff or other suitable section of the garment in direct contact with the skin of a grounded operator, or
- grounding the garment through a separate ground cord, directly attached to a designated groundable point on the garment.

5.3.3.4.7.3 Proper use

ESD control garments should be properly fastened to avoid exposure of possible charges on personal clothing worn under the ESD control garments.

Groundable static control garments and groundable static control garment systems should be connected to ground before ESDS are handled and should remain grounded whilst handling ESDS.

5.3.3.4.7.4 Testing

Procedures that can be used to test the electrical resistance of garments can be found in IEC 61340-4-9. For situations where the resistance testing as described in IEC 61340-4-9 is not applicable, the user of static control garments should select alternate test methods for product qualification and periodic verification. In these cases, the procedures that are chosen for use as well as the pass/fail criteria should be documented in the ESD control program plan. IEC TS 61340-4-2 describes some test methods that may be suitable.

5.3.3.4.7.5 Qualification

Qualification testing on static control garments that do not require grounding may be carried out on complete garments or, if electrical continuity across seams is not required, testing may be carried out on samples of fabric. Resistance testing as required by IEC 61340-4-9 is done on complete garments.

For static control garments that require grounding, groundable static control garments and groundable static control garments systems, testing fabric samples may be done to pre-select suitable fabrics, but qualification testing is done on complete garments so that electrical continuity throughout the garments can be checked.

Qualification testing on garments with ESD control properties that are claimed to be permanent should be done on two sets of samples: one set tested as received and the second set tested after cleaning according to the manufacturer's recommended cleaning method to simulate the long term use of the garments. Typically, samples should be cleaned a minimum of 50 times.

5.3.3.4.7.6 Periodic verification tests

Once garments have been placed into service it is recommended that they are checked on a periodic basis to ensure that they still meet the required specifications. This can be done as part of a random test of employees as part of the compliance verification measurements or a cleaning service (if used) can perform the checks after every cleaning cycle.

Consideration should be given to the frequency of testing based on the technology used to achieve ESD control performance, and the cost of testing relative to the cost and consequences of ESD failure.

ESD control garments that rely on topical treatment or non-permanent antistatic additives are likely to require more frequent periodic testing than ESD control garments that are made from fabrics with conductive fibres or permanent antistatic additives, and should, as a minimum requirement, be tested before being put back into service after cleaning.

5.3.3.4.7.7 Maintenance and cleaning

5.3.3.4.7.7.1 Repairs

Garments that become worn or damaged should be replaced on a like-for-like basis, or repaired by a qualified source in accordance with manufacturers' recommendations to ensure the integrity of ESD control properties, including electrical continuity across seams where required. Once a repair is made, periodic testing as described above should be conducted to validate the integrity of the repair before the garment is put back into service.

5.3.3.4.7.7.2 Laundry services

It is important to select an acceptable laundry service that has the ability to launder garments according to the garment manufacturer's prescribed laundry methods. Laundering should clean garments of all unwanted matter without unduly affecting ESD control properties. Thorough rinsing should be included in the laundering process to ensure that residual detergent and other laundering chemicals are removed.

If topical treatments are to be applied, launderers should be advised of the performance requirements, including the range of humidity conditions in which garments are intended to be used, and the total duration of wear between cleaning cycles, so that appropriate treatments are used. An auditable tracking system is recommended to monitor cleaning, which should be documented in the ESD control program plan.

5.3.3.4.7.7.3 Home laundering

If garments are being laundered at home by individual employees, it is important that the manufacturer's home laundering instructions be provided and followed. Periodic testing as described above should be conducted to verify the integrity of ESD control properties before the garments are put back into service.

5.3.3.4.7.8 Environment and humidity

Most fabrics from which garments are made will be affected to some extent by changes in relative humidity. ESD control properties of fabrics containing cotton, which are inherently hygroscopic, are very much dependent on relative humidity. Synthetic fabrics, such as polyester, nylon, etc., are very much less hygroscopic than cotton and their ESD control properties are not so dependent on relative humidity. Nevertheless, humidity may enhance the connection of any conductive fibres that are present in synthetic fabrics, and may increase the conductivity of topical treatments and antistatic additives. For these reasons, it is advisable to test garment performance in the full range of relative humidity and temperature in which garments will be used.

5.3.3.4.7.9 Other considerations

The procedures and equipment described in this user guide may 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. Users are cautioned that this document cannot replace or supersede any requirements for personnel safety.

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

Personnel safety should be considered before allowing ESD control garments to be worn where there is the possibility of exposure to mains electricity. Follow your organization's safety regulations or national rules.

Staple fibres may be released from woven or knitted fabrics, causing potential contamination issues, for example metallic fibres causing shorts. In such cases, consideration should be given to using continuous filament synthetic fabrics or non-woven fabrics.

5.3.3.4.8 Storage racks and shelving

5.3.3.4.8.1 Types of storage racks

Storage rack systems are used to store products and materials. Various styles and configurations are available but for the purposes of this user guide, two generic types of storage systems will be described.

5.3.3.4.8.2 Workstation shelving

Shelving systems are frequently included as part of an ESD protective workstation. The shelves in these systems can be used to store ESD sensitive products (both packaged and unpackaged), documentation, manufacturing tools, computer/printing equipment and test equipment such as oscilloscopes. If the shelving system is used to store unpackaged ESD sensitive products, then it should be treated as an ESD control worksurface. This means that the surface should be properly grounded and be free of unnecessary static generators.

However, if the shelving only holds ESDS that are inside ESD protective packaging then the shelf can be constructed from non-ESD protective materials.

One of the problems found in many factories is that the use of shelving systems changes at each process step. This results in the use of ESD control shelving in some areas and non-ESD control shelving in other areas. This can lead to confusion and employee mistakes as they may place ESD sensitive parts on shelves that are not grounded. One approach to solve this problem is to treat all shelves in a similar manner – i.e. they are all covered with an ESD control worksurface material and grounded, or they are not. If this is not practical then the only alternative is to place signs on the shelves to identify which ones are not covered with an ESD protective material.

NOTE This implies that those shelving units without any signs are covered with a grounded material.

5.3.3.4.8.3 Storage area shelving (warehouse, kitting, etc.)

The second type of shelving system that is commonly found in factories are floor or desk mounted, multi-level shelving units that are used for the storing of parts in a warehouse or parts kitting area. The user should decide whether or not this type of shelving requires a grounded, ESD control surface. Some of the factors to consider are as follows.

- Are unprotected ESD sensitive products stored next to non-ESD sensitive products that have been shipped in static generating packaging materials?
- How are products dispersed to and received from production?
- Is the packaged product moved to an ESD protective workstation where trained and grounded operators safely handle the parts?
- Are parts removed from their original packaging at the shelving units and are proper ESD handling procedures being followed?

Once a strategy has been decided upon and implemented, the testing of ESD control shelving units needs to be included as part of the regular process compliance verification program. The resistance to ground and resistance point-to-point test methods required by IEC 61340-2-3 are used to make the required compliance verification measurements. Generally, the same requirements as established for worksurfaces are applied to shelving systems.

5.3.3.4.9 Mobile equipment

As the name implies, mobile equipment are items that are capable of being moved from one process step to another as the need arises. Examples of mobile equipment are portable task carts, in-process storage carts and mechanized skids that are used to move heavy assemblies. When mobile equipment is used to transport ESD sensitive items it should be capable of being grounded as products are loaded and unloaded from it. When the mobile equipment is in an ungrounded state (i.e. between ESD protected areas), care should be taken to ensure that personnel do not handle the products unless they first bring all items to an equipotential balance by bonding together the product, mobile equipment and the personnel that handle the ESD sensitive products.

Mobile equipment can be grounded directly to ESD control floor materials via drag chains, conductive wheel(s) and cable or ball assemblies. When mobile equipment is grounded through floor materials it is necessary to ensure that there is a path to ground from the surface (where the unprotected parts are stored) to ground, no matter which connection method is chosen. One of the benefits of this type of system is that the connection to ground is constant and normally does not require operator intervention. One of the drawbacks is that the connection to ground can be lost if a reliable contact with the ESD control floor material is not achieved. Dust and dirt build-up (i.e. on the surface that contains ESDS parts, the floor and/or the grounding mechanism), can result in a loss of the electrical connection between the ESDS item and ground.

For ESD control programs that do not utilize ESD control floor materials, mobile equipment can still be used effectively to transport ESD sensitive products. In this situation, the mobile equipment will need to be connected to ground via a wire connected to the ESD grounding system prior to product loading and unloading. The mobile equipment should be connected to ground per the recommendations found in the grounding section of this user guide.

In both of the above cases, it will be necessary to include all pieces of mobile equipment in periodic compliance verification. IEC 61340-5-1 requires that the resistance to ground from the surface of the mobile equipment and point-to-point resistance of the surface in contact with ESDS is less than 1,0 x 10^9 Ω. In situations where CDM damage is a concern, a minimum point to point resistance limit of 1,0 x 10^4 Ω is recommended. The test procedure and equipment referenced in IEC 61340-2-3 can be used to make the resistance measurements.

5.3.4 Packaging electronic products for shipment and storage

5.3.4.1 Introductory remarks and purpose

The purpose of subclause 5.3.4 is to provide general guidance for the design and specification of ESD protective packaging systems. Packaging refers to those items and materials that provide intimate protection for ESDS parts during all phases of handling, shipping and storage. Secondary or exterior packaging is not specifically considered unless it also performs an ESD protective function. Within the ESD industry, there are many items and materials that are considered appropriate for packaging. Subclause 5.3.4 provides basic information to guide the reader to a better understanding of this complex area of packaging of ESD sensitive parts for shipment. While our principal concern is with electrical considerations, other factors related to physical properties are mentioned.

5.3.4.2 Definitions

5.3.4.2.1 General

The definitions used in this subclause follow the definitions of IEC 61340-5-3. The definitions as explained here provide an overview of the terms used.

5.3.4.2.2 Conductive

Conductive materials are generally composed of several components, including a base material that may be a polymer of some type. Additives to the base material or polymer generally make materials volume and surface conductive. Treatments, plating or coatings generally result in the formation of the so-called surface conductive materials which are typically not volume conductive. In some cases foils are also used to produce surface conductive materials.

5.3.4.2.3 Shielding (electrostatic)

Electrostatic field shielding, as produced with thin conductive ESD protective materials, tends to spread or reduce the electrostatic field inside the container due to external electrostatic fields.

Some designs of shielding materials, such as those incorporating a dielectric layer within the system, may also limit electrical current from penetrating the surface during a direct discharge. These types of products would be classified as electrostatic discharge shielding materials.

5.3.4.2.4 Dissipative

Dissipative materials provide charge dissipation. They also reduce areas of high charge concentration by allowing charges to spread out over the entire surface. Dissipative materials are not necessarily low charging. Additives to the base material or polymer generally make materials volume and surface dissipative. Treatments, plating or coatings generally result in the formation of the so-called surface dissipative materials which are typically not volume dissipative. In some cases foils are also used to produce surface dissipative materials.

5.3.4.2.5 Low charging

Low charging materials per se do not exist but are said to be those that resist triboelectric charge generation caused by the material contacting and separating from itself or from other materials. However the charging is strongly dependent on the material combination and its surface structure properties. Low charging behavior is not necessarily predicted by surface or volume resistance measurements. Low charging materials are not necessarily dissipative (although many are). Low charging is not specified in IEC 61340-5-1 nor in IEC 61340-5-3 at this time, because the measurement is strongly dependent on the application. However, it can be an important consideration for packaging material selection. Users of packaging materials are encouraged to determine the extent that the packaging materials that are selected will charge in the end use environment.

5.3.4.2.6 Insulating

Insulating materials have a very high resistance and this limits the ability of the material to conduct current. In general, insulating materials can become highly charged through contact and separation with other materials. The dissipation of charge from insulating materials via grounding may take a long time (i.e. hours or weeks depending on the environmental conditions). This makes insulating materials generally unacceptable for use near ESD sensitive products.

5.3.4.3 Selecting/designing the right package

What is the right packaging choice for a given application? How do you know? The vast number of packaging options available often causes confusion with uninformed users of packaging materials. Packaging used within an EPA shall consist of dissipative or conductive materials for intimate contact. Outside the EPA IEC 61340-5-3 requires for transportation of sensitive products a packaging that provides both

a) dissipative or conductive materials for intimate contact and

b) a structure that provides electrostatic discharge shielding.

The following six steps can be used as a guide for the development of an ESD protective packaging system.

1) Understand the product's sensitivity.
2) Determine the distribution environment for the packaged product (i.e. usage inside an EPA or outside an EPA which is then called UPA).
3) Determine the type of packaging system that will be used (i.e. returnable, disposable, etc.)
4) Select the packaging materials and qualify the materials according to IEC 61340-5-3.
5) Design a packaging system based on input considerations obtained in steps 1) to 4) above.
6) Test the final packaging design for effectiveness (if possible).

5.3.4.4 Understand the product sensitivity

Components are evaluated for ESD susceptibility by several different methods. The principle method is based on the human body model (HBM) in which a discharge is applied in steps through an RC (resistor-capacitor) network to all pins or connectors of the device under test (DUT). The DUT is evaluated for parametric shifts after each discharge. The level at which the device under test fails to meet any functional parameters defines the threshold of sensitivity for that component. Catastrophic failure levels may be used in many cases for specification purposes. Product ESD sensitivity information can be obtained by performing in-house evaluations, contacting the product manufacturer or by reviewing published ESD sensitivity data.

5.3.4.5 Understand the distribution environment

5.3.4.5.1 Factors for consideration

It is extremely important to understand the environment in which the product will be shipped and how it will be handled in order to determine the correct type of packaging that should be used.

Some of the questions that should be considered are:

- What is the distribution mode for the product?
  - within an ESD protected area (EPA);

  – between ESD protected areas (UPA's)

- Does the product cross national borders? If so, is it subject to inspection by untrained and ungrounded customs agents?
- Is the product being shipped by dedicated truck (only your organization's product on the truck) or is it part of a consolidated load?
- Does the shipment go directly to the final destination or does it go through various transportation hubs where it is loaded and unloaded (i.e. off of trucks/airplanes)
- What is the expected distribution environment?
  - temperature extremes (cold and/or hot);
  - moisture extremes (product exposed to high humidity or even outside threats such as rain).
- Who will handle the product at delivery?
  - employees trained in ESD handling techniques;
  - untrained individuals (customers, parts distribution companies).
- What measured ESD threats exist in the shipping environment?

5.3.4.5.2 Humidity

High humidity is known to cause multiple problems with electronic parts, not the least of which is enhanced corrosion. Difficulties with soldering are also well known and documented. Preventing excessive humidity exposure to parts requires enclosing the parts in a barrier material and the package itself should have a low moisture vapour transmission rate (MVTR).

5.3.4.5.3 Temperature

While only specialized materials and structures can control the interior temperature of a package, it is important to take possible temperature exposure into account when shipping electronic parts. It is particularly important to consider what happens to the interior of a package if the environment has high humidity. If the temperature varies across the dew point of the established interior environment of the package, condensation may occur. The interior of a package should either contain desiccant or the air should be evacuated from the package during the sealing process. The package itself should have a low moisture vapour transmission rate (MVTR).

5.3.4.6 Determine the type of packaging system that is best suited for the intended application

5.3.4.6.1 General considerations for packaging types

The marketplace provides numerous options for packaging of electronic products for shipment. The initial consideration is to have low charging or electrostatic dissipative materials in contact with ESD sensitive items. An additional benefit of low charging materials is the reduction of static charge carrying materials in the environment where sensitive items may be exposed. In addition, many organizations also require that the packaging protect the contents from a direct electrostatic discharge or exposure to electrostatic fields. Many packages are available that provide all three benefits: low charging, electrostatic dissipative and discharge protection, and electrostatic field suppression.

Subclauses 5.3.4.6.2 to 5.3.4.6.4 provides a description of some of the packaging types that are available to the packaging designer. It is not intended to be an all-inclusive list but it does address the major categories.

5.3.4.6.2 Returnable and reusable packaging

In some situations, packaging may be designed for reuse or return to the original supplier. In this way the package may be reused numerous times. Examples of these types of ESD protective packaging are hinged containers, tote boxes, and other rigid or semi-rigid containers. The initial cost of these packages may be relatively expensive. However, if the appropriate collection and recycling system is used, the container may be the least expensive choice over time.

Users of returnable packaging systems should ensure that they investigate the total cost to implement such a program. Some of the potential cost considerations include:

- labour to collect, sort and prepare materials for the return shipment,
- costs for cleaning prior to reuse,
- testing costs (i.e. surface resistance or point-to-point resistance) prior to re-introducing the packaging into the process,
- freight charges.

Bags and pouches may also be used in a returnable situation if the functional and performance characteristics continue to meet the original specifications.

Some packaging can be evaluated by the user in relatively simple ways to determine whether or not it is suitable for reuse. For example, the conductive or dissipative properties and other physical attributes of volume conductive or dissipative bags and boxes can be easily measured as per the test methods referenced in 5.3.4.7. Shielding bags and containers also may fall into this category as long as the metal layer may be tested for continuity, integrity, or shielding performance.

5.3.4.6.3 Disposable or one time use

Many bag type products are meant for one time use. Although the initial cost may be less than the reusable products, a cost/benefit analysis should be made in evaluating the overall performance of the packaging material for the intended purpose.

5.3.4.6.4 Point-of-sale or display

Computer dealers and other retail and wholesale outlets provide upgrade and replacement parts to the general public. While durability may not be a prime consideration for these applications, attractiveness and aesthetics generally appeal to the consumer. Such packaging usually contains printing that provides information on handling the part. Warning labels stating that the enclosed part may be sensitive to ESD are common.

5.3.4.7 Select and test packaging materials

Test methods and guidance for evaluating the ESD protection attributes of packaging materials are widely available in the industry. Electrical properties are used to define material types. The test methods described in IEC 61340-5-3 will allow the user of packaging materials to classify the materials as conductive, static dissipative or insulating. Once materials have been classified the design of the packaging can be started.

5.3.4.8 Design the packaging

With the ESD sensitivity and distribution environment of the ESD understood, and with a list of available materials for a variety of packaging designs, a packaging system can be designed.

The following general rules can be applied to packaging designs.

- If the package is primarily used to transport product in an ESD protected environment then a low charging or electrostatic dissipative package may suffice.
- If the product is moving between ESD protected areas a low charging, discharge shielding package might be required.

- When the package is outside an EPA a low charging, electrostatic dissipative and discharge shielding package is recommended.

5.3.4.9 Other design considerations

5.3.4.9.1 Cost/value relationship

Cost of packaging versus the total value of the system is an important consideration. Most organizations that build electronic parts categorize their items on a cost/value basis. The tendency is to use less costly packaging for the less costly or less valuable parts. While this seems logical, the added costs for carrying multiple inventories of packaging and ensuring that the intended package is used for the specified part increases the overall cost of implementing the system. Multiple packaging systems should be evaluated in a thorough cost/benefit analysis.

5.3.4.9.2 Handling

Anticipated rigorous handling for vibration sensitive parts requires packaging systems that provide cushioning or reduced stress from physical shock. Durable exterior or primary packaging is of prime importance. Packaging engineers normally design the shipping container to meet the maximum expected physical trauma. From an ESD perspective, the interior of the shipping container or the intimate package should also provide the required ESD protection. The primary container may or may not incorporate ESD protective elements.

5.3.4.9.3 Non-electrical considerations

In addition to electrical considerations, other attributes may be required to develop the best package for the intended application. Cleanliness, chemical transfer, plastic compatibility, bar code reading, transparency, testability, strength, and protection for shock and vibration are some of these additional characteristics that a specifier may need to consider.

5.3.4.10 Simulated use testing

There may be occasions where it is necessary to demonstrate that the product will not be damaged during transit to the customer. In these situations it is highly recommended that the packaged product be subjected to the types of hazards that it can be expected to see during shipment. Possible tests include but are not limited to the following.

- High voltage discharges to the exterior of the package. The discharge waveform shape and the voltage level selected should be based on the expected threats that the packaged product will be exposed to during shipment.
- Simulated over the road vibration. This test not only helps to ensure that the vibration will not adversely affect the product physically but can also check the charging relationship between the product and the package.
- Drop tests will ensure that the package provides adequate mechanical protection for the packaged product.
- Environmental exposure (rain, temperature and humidity extremes).

The product should be examined as well as functionally tested to ensure that it still meets all functional parameters. The user should establish pass/fail criteria as part of a test plan before any testing is initiated.

5.3.5 Marking

5.3.5.1 General

IEC 61340-5-1 requires that the organization mark ESDS assemblies and equipment in accordance with customer requirements. When marking is not specifically required the organization should determine whether a marking strategy is required.

Markings on ESDS and ESD packaging materials exist to inform users that the devices or the devices within packages are susceptible to ESD.

5.3.5.2 Marking of assemblies and equipment

Marking of hardware items (assemblies and equipment) can be accomplished by using the symbol shown in Figure 9. Marking of hardware is dependent on space available on the item itself as well as the environment the item will operate in and whether marking will hinder the operation of the item. Some hardware labels might contain nomenclature along with the symbol in Figure 9.

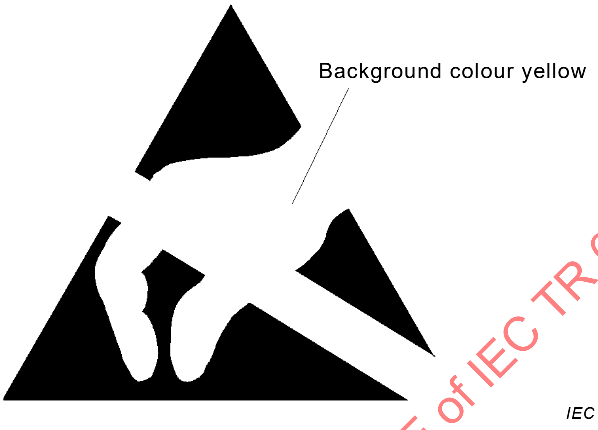


Figure 9 – ESD sensitive part or assembly

Wording such as, "ATTENTION, STATIC SENSITIVE DEVICES, Handle Only at Static Safe Workstations" or "ATTENTION – Sensitive Electronic Devices" may be included, depending on available space. An example of a warning label can be found in Figure 10.

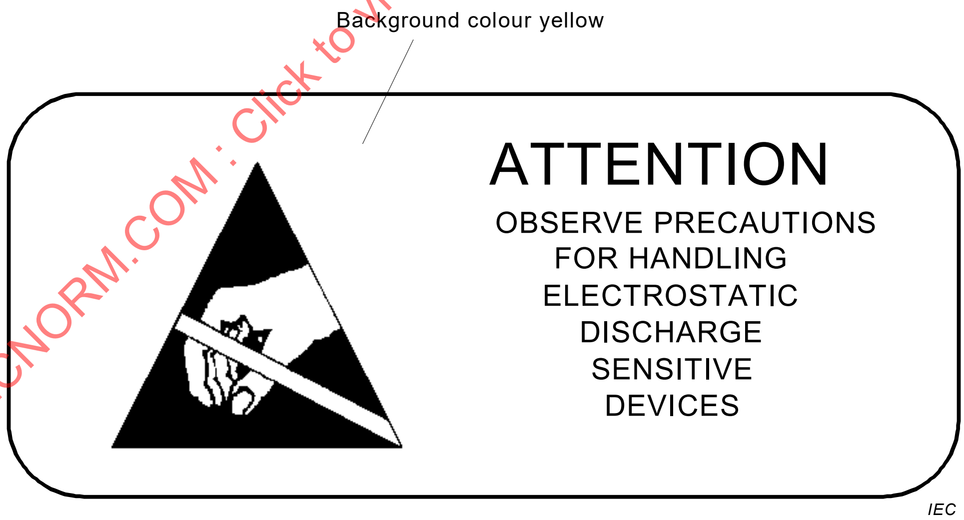


Figure 10 – Example of a warning label for ESDS

5.3.5.3 Marking of packaging

Marking of packaging materials, when ESD sensitive parts or assemblies are packaged inside (i.e. bags, pouches, fast packs, shipping containers, totes, etc.), can be accomplished by using the same symbol shown in Figure 10. Typically, if multiple packaging materials are used for each ESDS item (i.e. wrap and pouch or fast pack), the outermost package should have the label on both sides and clearly visible to handling personnel. Packaging labels may also contain wording along with the symbol shown in Figure 10.

In addition, it is strongly recommended that, where possible, the packaging be identified as ESD protective by using the label in Figure 11.

IEC 60417-6202:2013-06

Key

*	Primary function codes:
S	electrostatic discharge shielding
F	electrostatic field shielding
C	electrostatic conductive
D	electrostatic dissipative

Figure 11 – Example of a packaging label

5.3.5.4 Other marking considerations

Marking is sometimes used on other items that may be deemed a package, container or storage device by the organization. Items like storage cabinets or bins, shelving, and other items may be marked. The extent to which the organization wishes to mark hardware and packaging materials should be included in the organization's ESD control program plan. Again, some contractual agreements may dictate marking requirements by an organization.

ESD protective materials and equipment may also be marked. The organization should always be sure that the materials being marked have met qualification, acceptance and in-use criteria before utilizing such marking techniques. Marking of incoming materials and equipment does not always mean they meet requirements set forth by the organization. If marking of materials for ESD process control are used, the symbol should be the same as the one identified in Figure 12. Other material testing standards may already include marking requirements that are necessary prior to acceptance.

IEC 61340-5-3:2015

Figure 12 – ESD control material marking

6 Automated handling equipment (AHE)

Automated handling equipment used with unprotected ESDS should be qualified prior to use. AHE is a broad term and covers a large range of equipment types. This variation makes the development of a single test standard difficult. IEC 61340 (all parts) does not currently have test procedures for evaluating AHE. However, there are some generally accepted guidelines which can be used when selecting AHE.

The following are some suggested guidelines for automated handling equipment design, construction and testing.

NOTE With today's technology many plastics can be made dissipative with the addition of suitable compounds, which can then be grounded.

- All conductive and static dissipative materials should be bonded to the machine ground.
- All insulating materials within 30 cm of a device's critical path should be shielded, coated, plated, or otherwise rendered static safe.
- Equipment handling sensitive devices should have designated operator ground point(s).
- Where possible, all machine components that contact device leads should be static dissipative and grounded so as to prevent CDM (charged device model) type damage.
- Where possible, all machine components separated from the chassis by bearings of any kind (solid, rolling, radial linear, etc.) should be grounded in a manner that will provide a constant connection to ground regardless of rotary or transitional rate. This may include but is not limited to: flexible ground conductors (i.e. braided cables), metal brushes, graphite commutators, beryllium copper commutators, conductive greases, etc.
- Any surfaces on which operators may be prone to place devices should be static dissipative and grounded.
- Device pick-up mechanisms such as vacuum cups, nozzles and grippers should be conductive or static dissipative and grounded.
- Designated ESD ground points should all be directly connected to the equipment ground.
- Where possible, all machine conductors (wires and components), which are relied upon to provide a ground path, should be connected to the machine's primary ground point in a manner which will provide sufficient strength such that it may not be inadvertently disconnected.
- For anodized surfaces – ensure that the underlying conductive substrate is directly connected to the equipment ground point.

7 ESD control gloves and finger cots

7.1 Introductory remarks

Many of the electronic products that are handled by personnel during the manufacturing process should be protected from the oils and other contaminants that can be found on human skin. To prevent the transfer of these contaminants to the products being handled, operators are often required to wear gloves on their hands or finger cots over their fingers.

Gloves or finger cots may also be required to improve grip when handling products or tools.

In some situations, personnel may be exposed to hazards (chemicals, sharp edges, cold temperatures, etc.) that require protective gloves to be worn. It is beyond the scope of this document to address the requirements for personal protective equipment (PPE), but users are advised to take notice of and comply with any local or national regulations relating to gloves that are classed as PPE.

The procedures and equipment described in this document may 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. Users are cautioned that this document cannot replace or supersede any requirements for personnel safety.

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

The wearing of gloves and finger cots may be necessary for the reasons stated above, but in many cases the gloves and finger cots used are static generating. The static charge associated with the use of these products can potentially lead to ESD damage to ESD sensitive devices.

Another concern is that the wearing of gloves may increase the resistance to ground from hand tools and other conductors that are required to be grounded.

In order to properly select gloves and/or finger cots for use with ESD sensitive products the user should address ESD control properties as well as product contamination, ergonomics and personnel protection during the selection process. Clause 7 will address some of the ESD considerations related to gloves and finger cots. The test methods described may be used for qualification, acceptance or periodic verification testing.

7.2 Types

There are a variety of gloves and finger cots on the market, made from different materials. The major types of materials used to make ESD control gloves and finger cots are:

- latex;
- vinyl;
- nitrile;
- textile (uncoated);
- coated textile.

Latex, vinyl and nitrile gloves and all types of finger cots are typically intended for limited use, i.e. to be worn a predetermined number of times, often only once, and then disposed of. Textile gloves may also be for limited use, but are more often re-usable. If any gloves are to be re-used, an auditable tracking system is recommended to monitor the integrity of the gloves, which should be documented in the ESD control program plan.

Topical treatments or the use of antistatic additives in the polymer formulation are the most common means of providing ESD control properties in latex, vinyl and nitrile gloves and finger cots, and in the coatings on coated textile gloves. Topical treatments are also used on some textile gloves and finger cots. Care should be taken when selecting gloves and finger cots that use topical treatments or migratory antistatic additives to ensure that chemicals or additives used are not a possible source of product contamination.

Uncoated textile gloves and finger cots may contain conductive fibres. If product charging is the only concern, then surface conductive fibres or core conductive fibres can be used. If ESD gloves and finger cots are also required to maintain electrical continuity between ground and any handtools or other conductors held in the hand, then surface conductive fibres are more likely to be used. Core conductive fibres are unlikely to maintain a sufficiently low resistance unless topical treatments are also used.

Re-usable textile gloves may be laundered in the same way as ESD control garments (see 5.3.3.4.7.7.2 and 5.3.3.4.7.7.3), which may include the re-application of topical treatments.

7.3 Testing and qualification

7.3.1 Properties to test

The two properties of ESD control gloves and finger cots that should be tested are the degree to which products are likely to be charged and/or the ability to dissipate charge from any conductor held whilst wearing the gloves or finger cots.

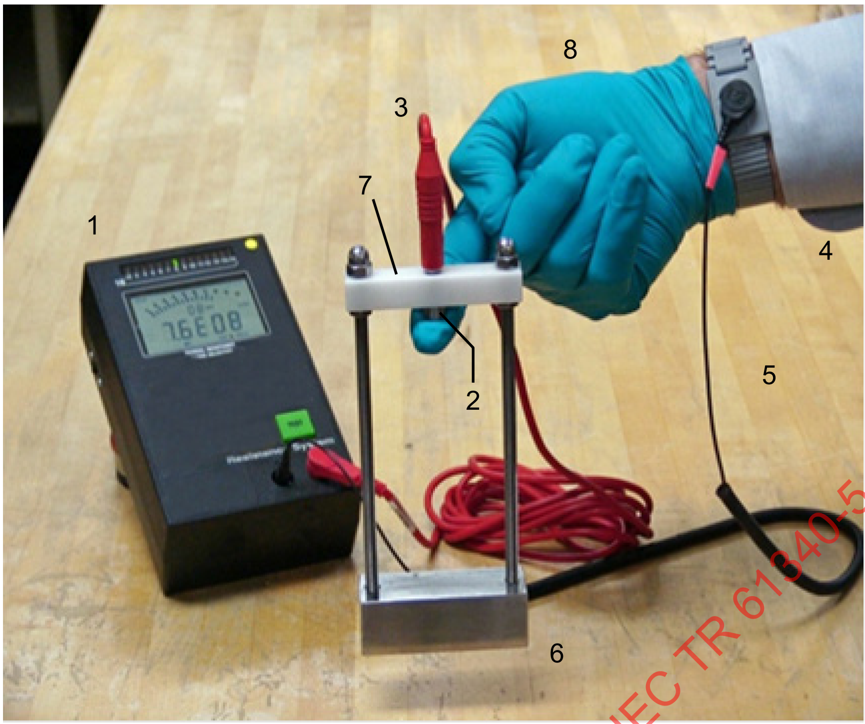
The test methods specified in IEC 61340-2-3 can be used, with suitable modification where necessary, to measure surface and volume resistance of gloves and finger cots, and the methods described below can be used to measure resistance to ground. However, care should be taken when using resistance measurements to test product charging because accurate correlation may not be possible, i.e. low resistance does not always mean low product charging. A direct measurement of charge generated when handling products is likely to be a more accurate way of testing product charging.

The ability of gloves and finger cots to dissipate charge from hand-held conductors can be tested by resistance measurements, or by charge decay time measurements as specified in IEC 61340-2-1.

For resistance, decay time and product charging test methods, the user should specify acceptance criteria until such time as industry agreed limits are established.

7.3.2 Resistance measurements

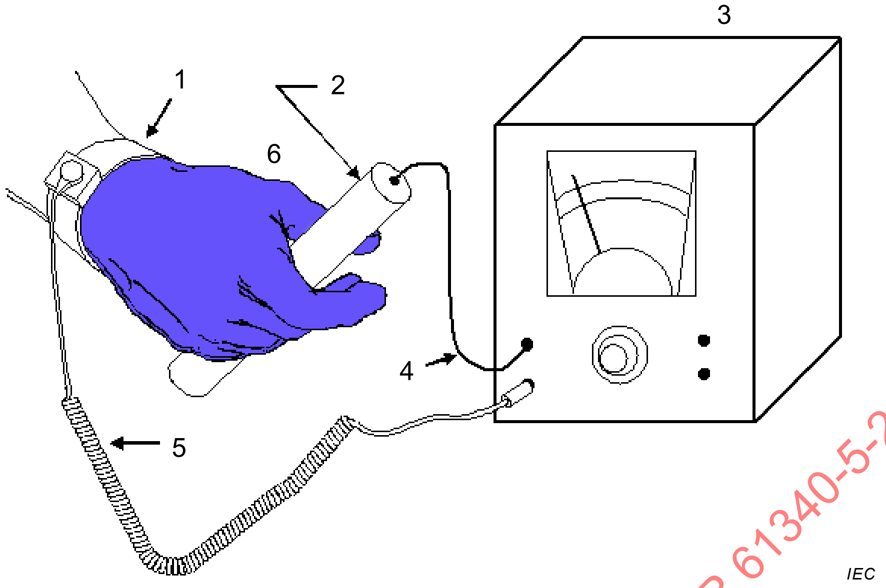
There is no specific test method in IEC 61340 (all parts) to measure resistance of gloves or finger cots. However, the test methods described in IEC 61340-2-3 can be modified to make surface and volume resistance measurements of gloves and finger cots. The resistance between the outside surface of gloves or finger cots and the body of the wearer can be measured, which in effect is the resistance to ground. An example of a resistance to ground test made while a glove or finger cot is being worn is shown in Figure 13 (according to e.g. ANSI/ESD SP15.1 For the Protection of Electrostatic Discharge Susceptible Items – In-Use Resistance Testing of Gloves and Finger Cots). In this example, a simple rig is used to produce a defined pressure between the contact electrode and the finger. Another example of how this measurement can be made is based on the wrist strap system continuity test specified in IEC 61340-4-6, as shown in Figure 14.



Key

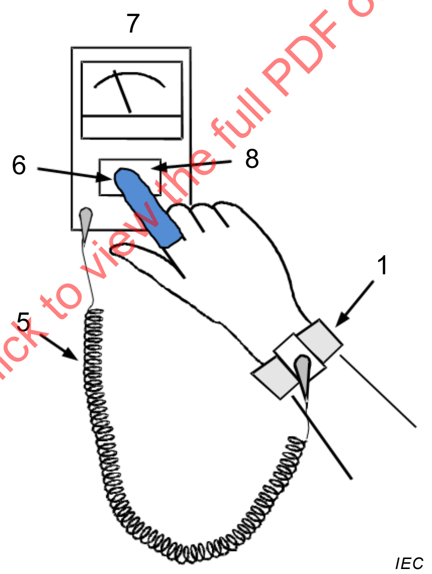
1	ohmmeter	5	ground cord
2	contact electrode	6	mass (used to control applied pressure)
3	ohmmeter lead	7	insulator
4	band	8	glove (or finger cot) under test

Figure 13 – Glove or finger cot resistance testing (as worn)



a) – Test using ohmmeter

When using this method for testing finger cots, ensure that the stainless steel electrode does not touch any part of the hand not covered by the finger cots under test.



b) – test using integrated checker

Key

1 band
2 hand-held stainless steel electrode
3 ohmmeter
4 ohmmeter lead
5 ground cord
6 glove or finger cot under test
7 integrated checker
8 contact plate

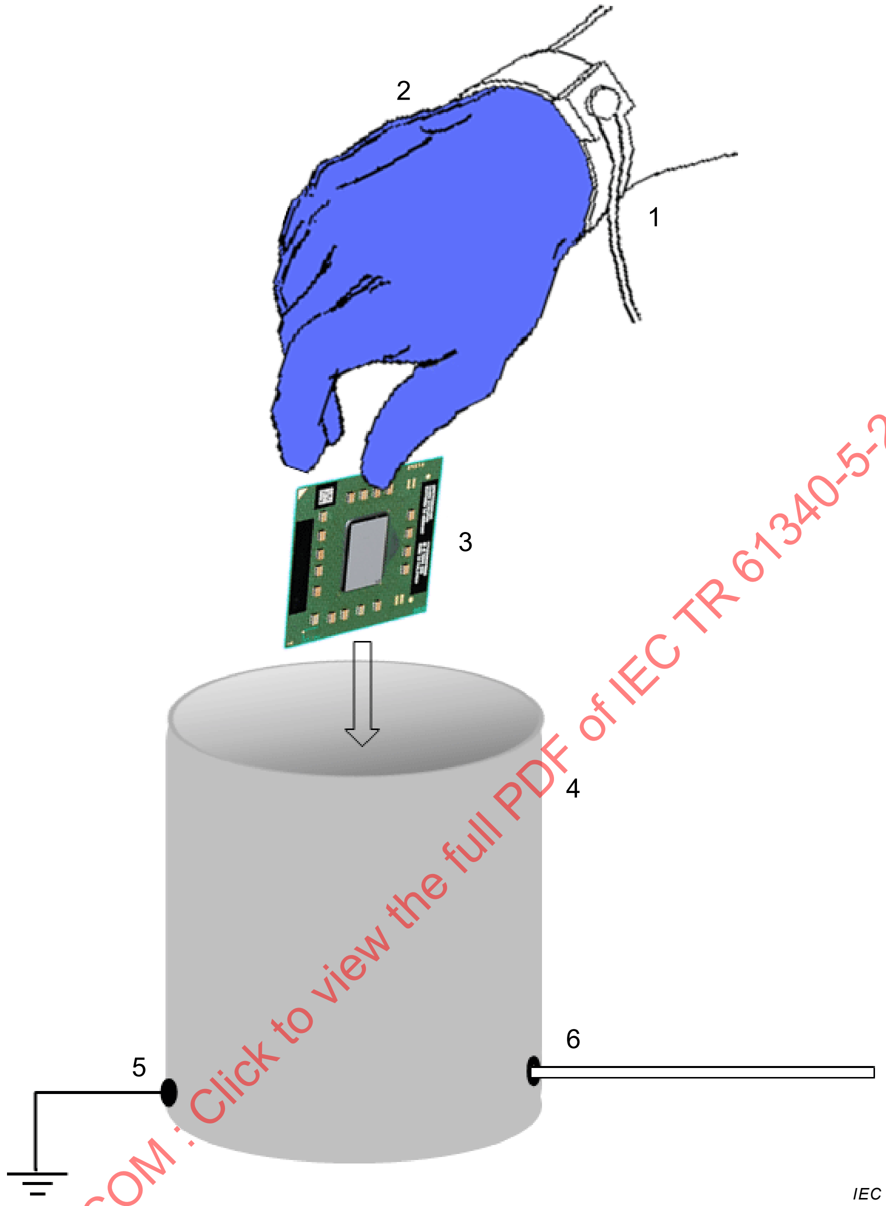
Figure 14 – Testing glove or finger cot resistance via a wrist strap system

7.3.3 Charge decay time measurements

IEC 61340-2-1 specifies a test method for measuring decay of charge from an isolated conductive plate via gloves and finger cots. In principle, the test method is the same as that used to measure decay time via hand-tools, see 8.2.2, but instead of the operator holding a hand-tool, a glove or finger cots are worn. It is also possible to carry out a full system check using this method to measure the decay time from the charged plate via a hand-tool, gloves or finger cots, person and wrist strap system.

7.3.4 Product charging test

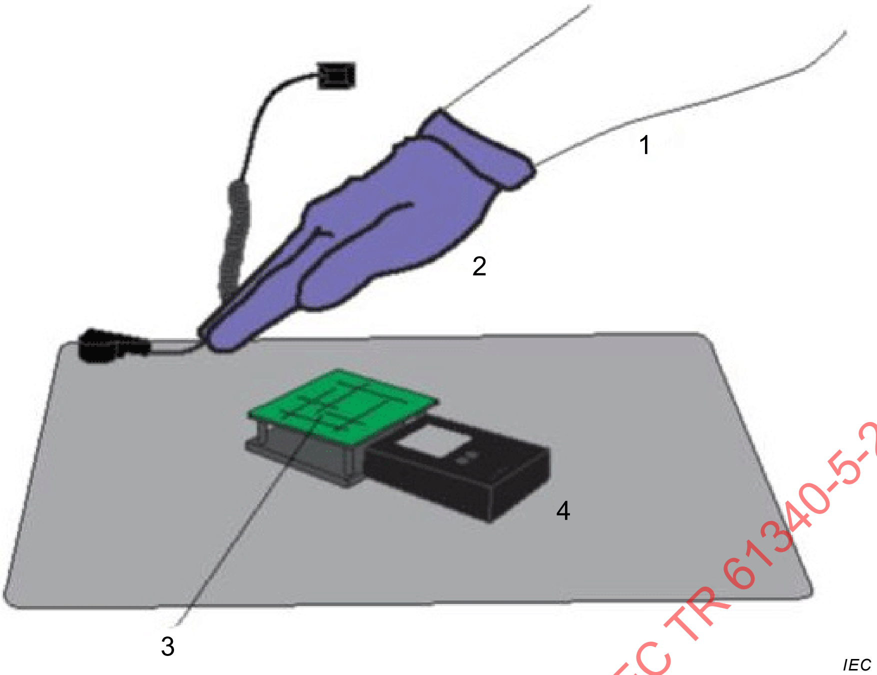
There is no specific test method in IEC 61340 (all parts) to specifically measure product charging, but IEC TR 61340-2-2 gives general guidance on chargeability testing. Examples of product charging tests are shown in Figure 15. In both these examples a grounded operator, wearing the glove or finger cots under test, handles a sample of the actual product and then places it into a Faraday pail (see IEC TR 61340-2-2), or on to a charged plate monitor. The operator's hand is then moved away (at least 1 m distance) and the measurement recorded. Interpretation of the results depends on the exact test methods and equipment used.



a) – Product charging test using Faraday pail

Key

1 grounded operator
2 glove (or finger cots) under test
3 sample of actual product
4 Faraday pail
5 shield ground connection
6 connection from inner container to measuring instrument



b) – Product charging test using charged plate monitor

Key

1 grounded operator

2 glove (or finger cots) under test

3 sample of actual product

4 charged plate monitor

Figure 15 – Product charging tests

8 Handtools

8.1 Introductory remarks

Handtools is a topic area that covers a wide range of products such as screwdrivers, lead cutters, tweezers, vacuum pick up tools. Depending on the tool design, these products can become charged during handling. If the charged part of the tool that contacts the ESD sensitive device is highly conductive an ESD event between the tool and the ESD sensitive part might occur.

Tools that contact ESD sensitive devices should be tested for their ability to charge due to handling. They also need to be evaluated to determine whether or not the charge can be removed when handled by a grounded operator or placed on a grounded surface. This requires some form of qualification procedure, by doing resistance measurements or by doing a decay time test, using a CPM (see IEC 61340-2-1).

8.2 Testing and qualification

8.2.1 Qualification criteria

Users are required to develop their own qualification criteria for handtools.

8.2.2 Resistance measurement

One approach that has been used successfully is to measure the resistance of the tool from the point that contacts the ESD sensitive device to the point that makes contact with the operator's hand. If this resistance meets the user's requirements it can be used with ESD sensitive devices. An example of this test approach can be found in Figure 16.

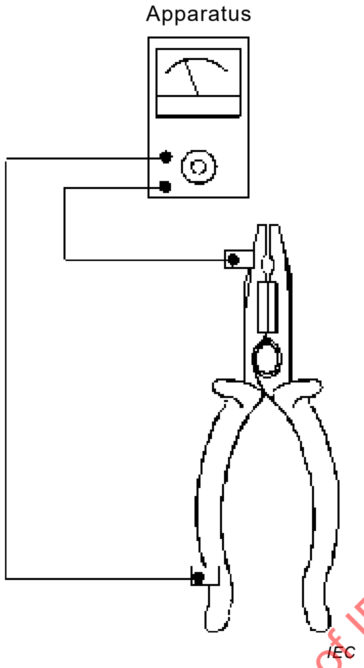


Figure 16 – Tool resistance test

A more convenient resistance to ground system test can be done by a grounded user holding the tool in their hand. A resistance meter is connected to ground, with its second terminal connected to a touch plate. This touch plate should be insulated well from ground. To test the tool system resistance to ground, the user holds the tool handle and touches the bit to the touch plate, and reads the resistance to ground from the meter (Figure 17a). The same system test can be used to test grounding of a tool held in a gloved hand (Figure 17b).