



## ESD CONTROL SURVEY INFORMATION

### BASED ON ANSI/ESD S20.20-2007

Standard for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

**Note:** This document is to provide the user with information about the Desco ESD Survey and is a helpful companion when reviewing Desco's ESD Survey Report. It is also intended to help educate and inform the user about ESD Control and the development of an ESD Control Program.

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## DESCO ESD SURVEY DEFINED

A Desco factory trained representative will walk with you around your facility resulting in a written report noting observations and measurements with the goal to assist you in to improving the overall quality of your ESD control program. A written report will be prepared with observations, measurements and specific recommendations for each of the Technical Elements. There will also be a Recommendations Summary, identifying those areas we believe to be most critical. A second document will accompany the ESD Survey Report, listing suggested ESD products for to specifically address problems or deficiencies found. We hope you will to consider incorporating these items into your Qualified Product Listing (QPL) for use in your program.

### ESD Association Standards

ANSI/ESD S20.20 – Standard for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices).

ANSI/ESD S541 – Standard for the Protection of Electrostatic Discharge Susceptible Items Packaging Materials for ESD Sensitive Items.

ESD TR53-2006 Compliance Verification of ESD Protective Equipment and Materials

ESD TR20.20-2000 Handbook ESD TR20.20 for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment

Both S20.20 and S541 are available at no charge and can be downloaded via [www.Desco.com/Standards.aspx](http://www.Desco.com/Standards.aspx). The ESD Association sells most of its documents. For a list of these and how to order, click "Standards" on the left column of the [ESDA.org](http://ESDA.org) web page home page.

S20.20 is a process standard and contains many parts for a complete ESD Control Program. The Desco Survey focuses primarily on the Technical Requirements section of the total ESD Control Plan.

### Use of Standards

Desco primarily uses S20.20 as the basis for performing ESD Surveys. The purpose of this standard is “to provide administrative and technical requirements, as well as guidance for establishing, implementing and maintaining an ESD Control Program”. The document is based upon protecting electronic parts, assemblies and equipment that is “susceptible to damage by electrostatic discharges greater than or equal to 100 volts Human Body Model”.

We assume that this 100 volt HBM level is the desired level of protection for your facility, and that ESD protective products are to meet the Required Limits of S20.20. In addition, S541 is used to evaluate packaging and material handling products. If you have a written ESD Control Plan, some of our recommendations may conflict with your performance requirements for ESD control elements.

Note: S20.20 allows the user to tailor their ESD Control Program per section 6.3. Tailoring, “This document, or portions thereof, **may** not apply to all applications. Tailoring is accomplished by evaluating the applicability of each requirement for the specific application. Upon completion of the evaluation, requirements **may** be added, modified or deleted. Tailoring decisions, including rationale and technical justifications, **shall** be documented in the ESD Control Program Plan.”

### Survey Goals

1. Evaluate that ESD protective products meet the Required Limits listed in Tables 1, 2, and 3 and are being used properly, and together as a comprehensive system.
2. Identify appropriate ESD protective products or improved methods consistent with ANSI/ESD S20.20 and ANSI/ESD S541 requirements and recommendations.
3. Make suggestions on how to improve the ESD control program in general.
4. The Desco ESD survey is not an audit replacing any part of your Compliance Verification Plan, nor is it a S20.20 certification assessment.

### Survey Vs. Audit

The Desco ESD Survey should not be considered a replacement for any part of the Compliance Verification Plan Audit, and is conducted independent of the written ESD Control Plan, and assumes that an initial process and organizational assessment has occurred. Unless noted, the Survey assumes one level of protection throughout the area surveyed. Many users find this survey useful and are invited to request surveys for other company locations and at supplier facilities in North America, Europe, or Asia.

## ESD CONTROL INTRODUCTION

Many electronic components and assemblies used in high technology products can be damaged or degraded by the sudden exchange of static electrical charges. This release of stored energy is called **ElectroStatic Discharge** or is most commonly referred to as **ESD**. Components that have a susceptibility to damage from electrostatic discharge are called ESD Sensitive or Susceptible or **ESDS**. These include transistors, diodes, laser diodes, electro-optical devices, precision film resistors, capacitors and an ever-increasing variety of integrated circuits. Susceptibility of devices to ESD is increasing with the drive to miniaturize electronic devices and increase operating speeds. Devices are subject to ESD damage at every stage of production from wafer fabrication to populated circuit boards in sub-assemblies and assemblies.

Devices are expected to become more ESD sensitive. "The ESD sensitivity of semiconductor components is routinely decreasing with each succeeding semiconductor generation. ... Technology trends in all areas of electronics production will make existing static problems worse." [page 19] "Technology trends towards finer line widths and higher speeds are producing devices of ever-increasing ESD sensitivities (Class 0) and Charged Device Model (CDM) mitigation is becoming more challenging. For instance, automation is becoming commonplace and is often the cause of CDM failures." [White Paper on Electrostatic Discharge (ESD) Phenomena LIMITATIONS AND TRENDS Page 11]

Therefore a more robust ESD control program likely will be desired. Users can select which ESD protective products, the Technical Requirements, to include in their ESD control program. "The selection of specific ESD control procedures or materials is at the option of the ESD Control Program Plan preparer and should be based on risk assessment and the established electrostatic discharge sensitivities of parts, assemblies, and equipment." [ANSI/ESDS20.20 Annex B]

"Any relative motion and physical separation of materials or flow of solids, liquids, or particle-laden gases can generate electrostatic charges. Common sources of ESD include personnel, items made from common polymeric materials, and processing equipment. ESD damage can occur when:

- i. A charged object comes into contact with an ESDS device, or
- ii. An ESDS device is grounded while exposed to an electrostatic field."

[ANSI/ESDS20.20 section Foreword]

### Fundamental ESD Control Principles

The fundamental ESD control principles are:

- All conductors, including personnel, **must** be electrically connected and attached to a known ground. This attachment creates an equipotential balance between all items and personnel. Electrostatic protection can be maintained at a potential above a "zero" voltage ground potential as long as all items in the system are at the same potential
- Ionization systems provide neutralization of charges on process necessary insulators and isolated conductors. Non-process necessary insulators **shall** be removed from the EPA.
- Transportation of ESD susceptible items outside an ESD Protected Area **requires** enclosure in static protective materials. Inside a Protected Area, low charging and static dissipative materials **may** provide adequate protection. Outside a Protected Area, low charging and static discharge shielding materials are **required**. (Ref: ANSI/ANSI/ESD S541 section 6.2)

## EFFECTIVE ESD CONTROL PROGRAM

An important component to an effective and consistent program is management support and the establishment of an ESD committee, with representation from all departments within an end user organization. An effective ESD control program can only be achieved and maintained if there is significant buy-in from the entire organization. An effective ESD committee will help to address and deal with existing and new ESD concerns to address as the needs of the organization change.

### 10 Steps To Developing An Effective ESD Control Program

1. Define what you are trying to protect, HBM of most sensitive item.

A prerequisite of ESD control is the accurate and consistent identification of ESD susceptible items. Some end users assume that all electronic components are ESD Susceptible, however, others write their ESD control plan based on the device and item susceptibility or withstand voltage of the most sensitive components used in the facility. Typically, the easiest way to establish the ESD susceptibility of ESDS items in your facility is to obtain the information from the component or sub-assembly manufacturer.

2. Span of the program
  - Define departments / areas to be covered
  - Define if customers and/or subcontractors included
3. Grounding - Define / Select Ground Reference
  - 3<sup>rd</sup>-wire / equipment ground is the preferred, recommended ground reference
4. Operator Grounding - Define how operators are grounded
  - Wrist Strap
  - Operator/footwear/floor
5. Establish & Identify EPA(s) – ESD Protected Area
6. Select ESD control elements
  - Worksurface
  - Flooring
  - Seating
  - Ionization
  - Shelving (stationary)
  - Mobile Equipment (Carts, Shelving, etc)
  - Garments
7. Develop Packaging (Materials Handling & Storage) Plan
8. Develop Compliance Verification Plan, see S20.20 section 7.3
  - “A Compliance Verification Plan **shall** be established to ensure the Organization’s fulfillment of the technical requirements of the ESD Control Program Plan. Process monitoring (measurements) **shall** be conducted”. The Compliance Verification Plan ” identifies the technical requirements to be verified, the measurement limits and the frequency at which those verifications **shall** occur.”
  - “The test equipment selected **shall** be capable of making the measurements defined in the Compliance Verification Plan.” “Compliance verification records **shall** be established and maintained to provide evidence of conformity to the technical requirements.”

9. Develop Training Plan – see S20.20 section 7.2
  - “Initial and recurrent ESD awareness and prevention training **shall** be provided to all personnel who handle or otherwise come into contact with any ESDS items.”
  - “The training **shall** include the methods used by the Organization to verify trainee comprehension and training adequacy.”
10. Document the Program – see S20.20 section 7.1
  - Training
  - Compliance Verification
  - Technical elements
  - Grounding system
  - Personnel Grounding
  - EPA Requirements
  - Packaging
  - Marking

#### **ESD Control Program – S20.20**

- “The Organization **shall** establish, document, implement, maintain and verify the compliance of the Program in accordance with the requirements of” S20.20. “An ESD Control Program Manager or Coordinator **shall** be assigned by the Organization to verify the compliance of the Program in accordance with the requirements of this document.” See S20.20 section 6.2
- S20.20 **may** not apply to all applications. Tailoring is acceptable and “is accomplished by evaluating the applicability of each requirement for the specific application. Upon completion of the evaluation, requirements may be added, modified or deleted. Tailoring decisions, including rationale and technical justifications, **shall** be documented in the ESD Control Program Plan.” requirements **may** be added, modified or deleted. Tailoring decisions, including rationale, **shall** be documented in the ESD Control Program Plan. See section 6.3
- The Organization **shall** prepare an ESD Control Program Plan that addresses each of the requirements of the Program. Those requirements include: Training, Compliance Verification, Grounding, Personnel Grounding, EPA Requirements, Packaging Systems, and Marking”. . See section 7.1
- “Additional items might include a list of approved ESD control products and materials”. See Handbook ESD TR20.20 section 4.1
- Additional items might include defined roles and responsibilities between the organization and subcontractors and suppliers”. See Handbook ESD TR20.20 section 4.1 and section 4.3.7.7 “Are subcontractors and suppliers of ESDS required to have ESD control programs and are they periodically audited?”

#### **Personnel Safety – see S20.20 section 5.0**

- The ESD control program “cannot replace or supersede any requirements for personnel safety”
- “Ground fault circuit interrupters (GFCI) and other safety protection **should** be considered wherever personnel might come into contact with electrical sources”. “Electrical hazard reduction practices **should** be exercised and proper grounding instructions for equipment **shall** be followed.”
- If personnel can come into contact with voltages over 250 volts, ESD personnel grounding products **should** not be used – see Handbook ESD TR20.20 section 5.3.2.7 and 5.3.13.6

## ESD SURVEY TECHNICAL ELEMENTS (WHAT WE LOOK AND TEST FOR)

### Grounding / Bonding System Used (See ANSI/ESD S6.1 – Grounding Standard):

“ESD Grounding / Bonding Reference Point: The ESD grounding system selected for use in a facility or situation that best suits the application.

- a) AC equipment ground
- b) Auxiliary ground
- c) Equipotential bonding”

[Grounding ANSI ESD S6.1 section 3.0 DEFINITIONS]

Check Ground, three-wire AC electrical outlets properly wired.

Test of AC outlets is performed using an AC Outlet Analyzer.

The hot, neutral, and equipment grounding conductor **shall** be verified to be in the proper wiring orientation in accordance with the National Electric Code (ANSI/NFPA-70).” [Grounding ANSI ESD S6.1 section 6.3.1 Equipment Grounding Conductor]

“Within an EPA, the AC equipment ground is the preferred ground when available. The equipment grounding conductor electrically bonds the AC equipment ground to the ground bus at the main service equipment panel of the facility. AC equipment within the EPA and all of the ESD technical elements will be at or near the same electrical potential when this system is used.” [Grounding ANSI ESD S6.1 section 5.1.1 AC Equipment Ground]

The single most important concept in the field of static control is grounding. Attaching all electrically conductive and dissipative items in the workplace to ground allows built-up electrostatic charges to equalize with ground potential. A grounded conductor cannot hold a static charge.” [Grounding ANSI ESD S6.1 Foreword]

“Isolated Ground: A separate equipment grounding conductor, which is only bonded to the ground bus (at the main service equipment) and a receptacle. It is permitted to pass through electrical panels, junction boxes etc., without being bonded to the equipment grounding conductor which services those devices. An isolated ground is not to be used to derive an ESD ground.” [Grounding ANSI ESD S6.1 section 3.0 DEFINITIONS] Note receptacle body typically identified orange in color and with green triangle on it.”

### Operator Grounding System Used:

- Wrist Strap – Required for all seated operations
- Continuous Wrist Strap Monitors - Optional
- Flooring – Footwear System – Optional for standing / mobile operations

**Wrist Straps worn and grounded when seated, resistance of operator-to-ground **must** measure <math>3.5 \times 10^7</math> ohms.**

Observations noted if any. Operator RTG can be tested using Resistance Meter. Isolate operator from contact with the Workstation, except for the Wrist Strap, properly worn and connected to ground. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb electrode and place in operators hand. Measured Resistance **must** be less than  $3.5 \times 10^7$  ohms, operator-to-ground.

“All personnel **shall** be bonded or electrically connected to the grounding / equipotential bonding system when handling ESDS items.” [ANSI/ESDS20.20 section 8.1]

“When personnel are seated at ESD protective workstations, they **shall** be connected to the grounding / equipotential bonding system via a wrist strap system.” [ANSI/ESDS20.20 section 8.2]

Handbook ESD TR20.20 section 5.3.2.2.1.1 Cuffs, “Wrist strap cuffs **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 cuff. 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..”

ANSI/ESD S1.1 section 5.4 Breakaway Force, "With the ground cord connected to the cuff in a normal manner, a force of >1 pound but < 5 pounds applied to the ground cord, in the normal disconnect direction, **shall** be required to separate the ground cord from the cuff."

Per ANSI/ESD-S1.1 section 6.1.3 Frequency of Functional Testing "Daily [Wrist Strap] testing **may** be omitted if constant monitoring is used."

"Even if the wrist strap is working properly, a bad or intermittent ground connection will render the wrist strap system less than 100% effective. ...Continuous monitors evolved as a means to evaluate the performance of wrist straps on a continuous basis, particularly in high value and high-risk operations"  
[Handbook ESD TR20.20 section 5.3.9.1 Continuous Monitors Introduction]

"Continuous wrist strap monitors **should** be tested (i.e. qualification, acceptance and in-use) to verify performance.... The user **should** follow manufacturer instructions for verification of wrist strap monitors.  
[Handbook ESD TR20.20 section 5.3.9.4 Performance Verification]

**ESD Footwear on each foot for mobile personnel. The Flooring-Footwear System when used as primary ground for personnel, RTG of operator, footwear, floor circuit **must** measure less than  $3.5 \times 10^7$  ohms Method 1 of S20.20 Table 2. For Method 2, both less than  $1 \times 10^9$  ohms and charge generation less than 100 volts are required.**

Operator RTG can be tested using Resistance Meter. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb electrode and place in operators hand. Measured Resistance **must** be less than  $3.5 \times 10^7$  ohms, operator-to-ground for primary ground applications (the handling of unprotected ESDS items without the use of a wrist strap). If footwear grounding is as a secondary ground (the handling of ESDS items within ESD Protective packaging) then higher resistance levels are acceptable as provided for in S20.20 by proper “tailoring” statements and documented rational.

Charge generation can be tested by connecting operator via a wrist strap to the conductive plate of a Charged Plate Analyser using a bulldog or alligator clip. Charge generated by operator making walking steps wearing ESD footwear on ESD floor will be much less than 100 volts unless some element is defective. Alternately, for an indication, the Ionization Test kit with Human Body Model fixture can be used. Ground the Static Field Meter, have operator hold the fixture portion and read approximate voltage.

See section on Flooring for additional information as the Floor (mats, painted, Floor Finish, Permanent ESD Floor, or a combination of these) is of paramount importance, especially when used as part of the Primary Grounding System for Mobile / Standing Operators.

“All personnel **shall** be bonded or electrically connected to the grounding / equipotential bonding system when handling ESDS items.” [ANSI/ESDS20.20 section 8.1]

“For standing operations, personnel **shall** be grounded via a wrist strap system or by a flooring/footwear system. When a flooring-footwear system is used, one of the two following conditions **shall** be met:

A. When the total resistance of the system (from the person, through the footwear and flooring to the grounding / equipotential bonding system) is less than  $3.5 \times 10^7$  ohms, Method 1 **shall** be followed (see Table 2).

B. When the total resistance of the system (from the person, through the footwear and flooring to the grounding / equipotential bonding system) is greater than  $3.5 \times 10^7$  ohms and less than  $1 \times 10^9$  ohms, Method 2 **shall** be followed (see Table 2).” [ANSI/ESDS20.20 section 8.2]

Note 2 “For situations where an ESD garment is used as part of the wrist strap grounding path, the total system resistance including the person, garment and grounding cord **shall** be less than  $3.5 \times 10^7$  ohms”.

ESD SP9.2 APPENDIX B - Foot Grounder Usage Guidance

“Compliance verification **should** be performed prior to each use (daily, shift change, etc.). The accumulation of insulative materials **may** increase the foot grounder system resistance. If foot grounders are worn outside the ESD protected area, testing for functionality before reentry to the ESD protected area **should** be considered.”

Personnel checklist “Are test records for wrist straps and foot grounders maintained? [Handbook ESD TR20.20 section 4.3.3.4] “Compliance verification records **shall** be established and maintained to provide evidence of conformity to the technical requirements.” [ANSI/ESD S20.20 section 7.3]

ANSI/ESD S20.20 Table 2 Flooring-Footwear System Required Limits Method 1 “less than  $3.5 \times 10^7$  ohms measured per ESD STM 97.1” , or Method 2 less than  $1 \times 10^9$  ohms measured per ESD STM 97.1 and “less than 100 volts measured per ESD STM 97.2.”

Footwear are an Optional Element within S20.20 Table 3 – EPA ESD Control Items

Per Handbook ESD TR20.20 section 5.3.3.3.4 Proper Usage “ESD protective footwear is designed to reduce body charge levels by supplying a conductive path from the body to the floor material. Heel and Toe grounders **should** be worn on both feet to insure effective use.”

Handbook ESD TR20.20 section 5.2.3 “If the contact area between the bottom of the foot and the floor is not continuous, charge generation **may** occur especially when a person is walking. Heel straps **must** be worn on both feet to minimize the amount of time that the body of the person is isolated from ground while walking.”

## Personal grounding devices ( Wrist Straps & Footwear) tested with results logged.

Observation: Are operators required to test personal grounding devices? How often? Are results logged?

"A Compliance Verification Plan **shall** be established to ensure the Organization's fulfillment of the technical requirements of the ESD Control Program Plan. Process monitoring (measurements) **shall** be conducted in accordance with a Compliance Verification Plan that identifies the technical requirements to be verified, the measurement limits and the frequency at which those verifications **shall** occur. The Compliance Verification Plan **shall** document the test methods and equipment used for process monitoring and measurements. If the test methods used by the Organization differ from any of the standards referenced in this document, then there **must** be a tailoring statement that is documented as part of the ESD Control Program Plan. Compliance verification records **shall** be established and maintained to provide evidence of conformity to the technical requirements. The test equipment selected **shall** be capable of making the measurements defined in the Compliance Verification Plan." [ANSI/ESDS20.20 section 7.3]

"All personnel **shall** be bonded or electrically connected to the grounding / equipotential bonding system when handling ESDS items." [ANSI/ESDS20.20 section 8.1]

"When personnel are seated at ESD protective workstations, they **shall** be connected to the grounding / equipotential bonding system via a wrist strap system." [ANSI/ESDS20.20 section 8.2]

Handbook ESD TR20.20 section 5.3.2.4.2 Additional User Wrist Strap Testing, "Proper testing of the wrist strap includes the resistance of the groundable point on the end of the cord, the cord itself, the resistor, the cord-to-cuff 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."

Personnel checklist "Are test records for wrist straps and foot grounders maintained? [Handbook ESD TR20.20 section 4.3.3.4]

"The wrist strap system **should** be tested daily to ensure proper electrical value. Nominally, the upper resistance reading **should** be <10 Megohms or a user defined value." [ANSI/ESD S1.1 section 3 Frequency of Functional Testing]

Handbook ESD TR20.20 section 5.3.2.2.2 Wrist Strap Ground Cord, "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."

### ESD Protected Area – Technical Elements Required.

- Signage – Required
- ESD Packaging (This includes bags and containers used for Material Handling, Storage, and Transport of ESDS items) - Required (Note: Inside the EPA, the following are Optional and at least one must be selected for the ESD Packaging used)
  - Conductive ( $<1 \times 10^4$  ohms)
  - Dissipative ( $\geq 1 \times 10^4$  to  $<1 \times 10^{11}$  ohms)
  - Shielding ( $<50$  nJ)
  - Low Charging

### ESD Protected Area Clearly Identified using signs & aisle tape.

Observations noted if any.

"Handling of ESDS parts, assemblies and equipment without ESD protective covering or packaging **shall** be performed in an EPA. NOTE: An EPA can consist of a single workstation, entire room or building. An EPA **shall** be established wherever ESDS [ESD Sensitive] products are handled. However, there are many different ways to establish ESD controls within an EPA. Table 3 lists some **optional** ESD control items which can be used to control static electricity. For those ESD control items that are selected for use in the ESD Control Program, the required limits and test methods for that item becomes **mandatory**." [ANSI/ESDS20.20 section 8.3]

ANSI/ESD S20.20 section 8.3. Protected Areas Requirement

"Caution signs indicating the existence of the Protected Area **shall** be posted and clearly visible to personnel prior to entry to the Protected Area."

Handbook ESD TR20.20 section 5.3.10 "Signs **should** be used in the following manners. Entrance of an ESD controlled area: Signs are posted to alert personnel and visitors that they are entering a limited access area where ESD protective precautions are required. In addition, the precautionary sign is indication that the total area includes the infrastructure necessary to support the ESD Control Program Plan requirements for the handling of exposed ESDS items."

### Inside the EPA – Packaging / Low Charging & Dissipative or Conductive Materials are used.

### Outside the EPA – Packaging / Shielding Bags or Conductive / Dissipative Shielding Totes with covered lid used to transport or store ESDS items.

Observations noted, if any, regarding proper procedures and use of materials. Resistance measurements of materials in question may be taken using Resistance Meter. A Static Field meter may be used to indicate if materials are low charging and/or groundable..

"ESD protective packaging **shall** be in accordance with the contract, purchase order, drawing or other documentation. When not specified by the above documentation, the organization **shall** define ESD protective packaging requirements, both inside and outside the EPA per ANSI/ESD S541." [ANSI/ESDS20.20 section 8.4]

ANSI/ESD S20.20 Section 8.3, Protected Areas Requirement, "Handling of ESDS parts, assemblies and equipment without ESD protective covering or packaging **shall** be performed in a Protected Area."

Per ESD S541 section 6.1 Inside an EPA, "Packaging used within an EPA (that satisfies the minimum requirements of ANSI/ESD S20.20) **shall** be:

1. Low charge generation.
2. Dissipative or conductive materials for intimate contact.

Per ESD S541 section 6.2 Outside an EPA, "Transportation of sensitive products outside of an EPA **shall require** packaging that provides:

1. Low charge generation.
2. Dissipative or conductive materials for intimate contact.
3. A structure that provides electrostatic discharge **shielding**."

Per ESD S541 section 7.2 Resistance Material Property, "Most standard packaging materials are electrically insulative, and insulative materials retain charge. Making the package less insulative provides a path for charge to dissipate from the package."

Per ESD S541 section A.3 "Dissipative Material for Intimate Contact, To avoid rapid discharge to sensitive items, dissipative materials **should** be used as the layer of packaging that contacts the item."

Per ESD S541 section A.6 Periodic Verification "The static control properties of some packaging materials can deteriorate with time and use. Periodic verification of static control properties **should** be considered."

Per ESD S541 section 8.2.1 Material Identification, “ESD protective packaging **shall** be marked with the ESD Protective Symbol.” And section 8.2.3 Traceability “Packaging **should** be marked with information that allows traceability to the packaging manufacturer and to the manufacturer’s date/lot code information. The date/lot code **should** allow traceability to quality control information pertaining to the manufacture of the specific lot of packaging.”

**ESD Protected Area – Technical Elements Optional.** “There are many different ways to establish ESD controls within an EPA.” Below are “some optional ESD control items which can be used to control static electricity. For those ESD control items that are selected for use in the ESD Control Program, the required limits (Table 3, S20.20) and test methods for that item becomes mandatory.” [ANSI/ESDS20.20 section 8.3]

**Identify which of the following are considered part of the ESD Control Program:**

- Worksurface
- Foot Grounders
- Flooring
- Seating
- Ionization
- Shelving
- Continuous Monitors
- Mobile Equipment (Carts)
- Garments

**Access to ESD Protected Area controlled – Training Issue, ESD Plan Issue.**

Observation: Controlled if only personnel who have received ESD Awareness training allowed in the EPA, visitors escorted.

“Access to the EPA **shall** be limited to personnel who have completed appropriate ESD training. Untrained individuals **shall** be escorted by trained personnel while in an EPA [ESD Protected Area].”  
[ANSI/ESDS20.20 section 8.3]

ANSI/ESD S20.20 section 7.2 Training Plan Requirement, “Initial and recurrent ESD awareness and prevention training **shall** be provided to all personnel who handle or otherwise come into contact with any ESDS items. ... The training plan **shall** include the methods used by the Organization to verify trainee comprehension and training adequacy.”

**ESD Protected Area Worksurfaces  $10^6$  –  $10^8$  ohm RTG, Properly grounded to common point ground, ESD Mat Cleaner used.**

Worksurface RTG measured by using Resistance Meter. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb. electrode and place in most used portion of the mat/worksurface. Measured Resistance **must** be less than  $1.0 \times 10^9$  ohms and **should** be  $>1.0 \times 10^6$  ohms.

If measurement is HIGH, out of spec, to check the resistance of just the worksurface material, Connect the lead from the AC Outlet Analyzer and attach a second 5 lb. Electrode. Place the second electrode 10" from the first electrode. This is an RTT (Resistance Top-to-Top) measurement.

If this measurement is  $>1.0 \times 10^9$ , clean the surface with good quality ESD Mat & Surface cleaner, let surface "air dry" for 15 minutes before re-testing.

After re-test, if this measurement is still  $>1.0 \times 10^9$ , consider mat/surface replacement. If measurement is  $<1.0 \times 10^9$ , re-test for RTG as above.

If RTG is  $<1.0 \times 10^9$ , make note of measurement, bench and that the mat needed cleaning. If RTG is  $>1.0 \times 10^9$  (with RTT  $<10^9$ ) we must start testing the mat/worksurface ground point connection, ground cord, and ground cord connection to ground.

Mat/Worksurface Top-to-Ground point connection: Place one 5 lb. Electrode on the mat surface and the other on the ground cord connection point on the mat – to be  $< 10^9$ . Replace snap if necessary.

Ground Cord – Using Fluke meter, measure resistance from Ground cord (part that connects to the mat) to ground. This should be  $<1$  ohm if no resistor in the ground cord and  $\sim 1,000,000$  ohms (1 megohm or  $1.0 \times 10^6$  ohms). Reconnect ground cord to ground connection or replace ground cord as necessary.

"An EPA **shall** be established wherever ESDS [ESD Sensitive] products are handled. However, there are many different ways to establish ESD controls within an EPA. Table 3 lists some optional ESD control items which can be used to control static electricity. For those ESD control items that are selected for use in the ESD Control Program, the required limits and test methods for that item becomes mandatory." [ANSI/ESDS20.20 section 8.3]

NOTE: While ESD Controlled worksurfaces are not specifically required within S20.20, generally this is one of the first of the elements selected.

ANSI/ESD S20.20 Table 3 Required Limit, "less than  $1 \times 10^9$  ohms measured per ANSI/ESD S 4.1 or ESD TR53" [however, specifies no lower limit]."

Per ESD S4.1 section 8. Resistance Guidelines "Resistance-to-groundable point  $1 \times 10^6$  to  $1 \times 10^9$  ohms. Resistance from point-to-point greater than 1 megohm. These **guidelines** represent a range of resistance that has generally been proven to provide protection in the manufacturing environment." Dirt & cleaners containing silicone are insulative and a dissipative ESD worksurface **may** not fulfil its function if covered by insulative material.

Handbook ESD TR20.20 section 5.3.1.7 Electrical Considerations "[RTG is] The most important functional consideration for worksurfaces. This establishes the resistance of the primary path to ground for items, placed on the surface. When worksurface materials are being selected, consideration **should** be given to possible Charged Device Model (CDM) damage to ESD sensitive products. If CDM damage is a concern then setting a lower resistance limit for the worksurface **should** be considered. Typically, the lower limit for these types of worksurfaces is  $1 \times 10^6$  ohms."

#### GROUNDING

ANSI/ESD S20.20 Section 6.2.1.1 Grounding / Bonding System Requirements "Grounding/Bonding Systems **shall** be used to ensure that ESDS items, personnel and any other conductors are at the same electrical potential."

"All of the grounding conductors from each of the ESD technical elements (excluding level 2 technical elements) used within an EPA **shall** be terminated at the same electrically equivalent point. The common point ground **may** be a terminal strip, bus bar or any other convenient configuration that is, within itself, electrically continuous to no greater than 1 ohm measured from point to point with an ohmmeter" [ANS/ESD S6.1-2005 section 5.2.1 Common Point Ground]

"The grounding conductors (wires) from wrist straps, worksurfaces, flooring or floor mats, tools, fixtures, storage units, carts, chairs, garments and other ESD technical elements **may** or may not contain added resistance. Where added resistance is not present, a direct connection from the ESD technical element to the common point ground or common connection point is acceptable and recommended.

"Note: Manufacturers **may add** resistance to the grounding conductors for purposes other than ESD (e.g. current limiting). Added resistance is acceptable for the purposes of controlling ESD provided electrostatic accumulation does not exceed specific EPA requirements. The typical added resistance in grounding conductors is 1 megohm, although other values **may** be specified." [ANSI/ESD S6.1 section 5.3.3 ESD Technical Element Conductors]

"The groundable end of the cord is most often equipped with a banana plug and a mating alligator clip. Any electrical connector that could be attached to ground would be acceptable as long as it was mechanically durable. The preferred grounding point for the groundable end of the cord would be a common point ground as defined in ESD S6.1, Grounding - Recommended Practice. Also, see the Grounding Section of this Handbook for further information.

Note: Many wrist strap users clip the wrist 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 35 megohm limit recommended in ESD S20.20." [Handbook ESD TR20.20 section 5.3.2.2.2 Wrist Strap Ground Cord]

Handbook ESD TR 20.20 section 5.1.3 Basic Grounding Requirements "The first step in ensuring that everything in an EPA is at the same electrical potential is to ground all conductive components of the work area (worksurfaces, people, equipment, etc.) to the same electrical ground point. This point is called the common point ground. The next step in completing the ground circuit is to connect the common point ground to the equipment ground (third wire, green)."

"The single most important concept in the field of static control is grounding. Attaching all electrically conductive and dissipative items in the workplace to ground allows built-up electrostatic charges to equalize with ground potential. A grounded conductor cannot hold static charge.

Electrically interconnecting all electrically conductive and dissipative items (bonding) allows charge to equalize across these items without actual contact to ground. This provides static control in areas where ground may not be accessible such as in field service environment.

Electrically bonded conductors and dissipative items share stored electrical charge and therefore have no difference in electrical potential between them. Electrostatic Discharge (ESD) susceptible parts can be handled within a bonded system without causing damage." [ANS/ESD S6.1 Foreword]

Handbook ESD TR 20.20 section 5.3.10 "Signs **should** be used in the following manners. ESD protective workstation: A sign is posted in a conspicuous location on the ESD protective workstation."

Per ESD 8.1 Symbols ESD Awareness section 5.1 Application "The ESD common point ground symbol **should** be used to indicate the location of an acceptable common point ground."

ESD-ADV53.1 ESD Protective Workstations Electrical Requirements "Workstation elements **shall** be connected to, and maintain electrical continuity to, the common point ground as follows:

Worksurfaces - Resistance: Between  $1 \times 10^6$  ohms and  $1 \times 10^9$  ohms

Surfaces of shelves and drawers intended to be used for unprotected ESD sensitive devices - Resistance: Between  $1 \times 10^6$  ohms and  $1 \times 10^9$  ohms"

**ESD Workstation Clear of Insulators such as regular high charging bags, packaging, document holders, binders & tape.**

Observations noted if any, measurement of charge on insulators using Field meter. Note that when using the Field Meter, both the operator and meter must be grounded. Generally, field meters are calibrated to a specific distance, like 1". In this case, the object being measured must be at least 3X the size of the distance (or 3" X 3") for an accurate measurement.

For accurate measurements, the object to be measured must be held in free space. Since we are looking for the "ability to be charged" it is appropriate to rub the object and then measure the charge.

"All nonessential insulators such as coffee cups, food wrappers and personal items **shall** be removed from the workstation or any operation where unprotected ESDS items are handled." [ANSI/ESDS20.20 section 8.3]

"All conductors in the environment, including personnel, **shall** be bonded or electrically connected and attached to a known ground". "Necessary non-conductors in the environment cannot lose their electrostatic charge by attachment to ground. ... Assessment of the ESD hazard created by electrostatic charges on the necessary nonconductors in the work place is required to ensure that appropriate actions are implemented, commensurate with risk to ESDS items. [ANSI/ESDS20.20 section Foreword]

Handbook ESD TR 20.20 section 2.4 "It **should** be understood that any object, item, material or person could be a source of static electricity in the work environment. Removal of unnecessary nonconductors, replacing nonconductive materials with dissipative or conductive materials and grounding all conductors are the principle methods of controlling static electricity in the workplace, regardless of the activity."

**ESD Floor (and/or mat) grounded & clean. Floor <10<sup>9</sup> ohms RTG to be considered “ESD Protective” and <10<sup>7</sup> ohms RTG for Primary Ground applications and/or less than 100 volt charge generation.**

Measurements noted. Floor or mat RTG measured by using Resistance Meter. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb. electrode and place in most used portion of the mat/worksurface. Measured Resistance **must** be <10<sup>9</sup> ohms or <10<sup>7</sup> ohms, depending on application.

Note: When doing floor measurements, the conductive pad on the 5 lb. Electrodes will gather dirt rapidly and thus should be regularly cleaned, a minimum 70% isopropanol-water solution is recommended.

If measurement is HIGH, out of spec, to measure the resistance of just the floor material, Connect the lead from the AC Outlet Analyzer and attach a second 5 lb. Electrode. Place the second electrode 30” from the first electrode. This as an RTT (Resistance Top-to-Top) measurement.

If this measurement is HIGH (>10<sup>7</sup> or 10<sup>9</sup> as appropriate), clean the surface with good quality ESD Floor or Mat & Surface cleaner as appropriate, let surface “air dry” for 15 minutes before re-testing.

After re-test, if this RTT measurement is still HIGH, (>10<sup>7</sup> or 10<sup>9</sup> as appropriate) consider mat/surface replacement. If measurement is within spec (<10<sup>7</sup> or 10<sup>9</sup> as appropriate), re-test for RTG as above.

If RTG is in spec (>10<sup>7</sup> or 10<sup>9</sup> as appropriate), make note of measurement, area and that the Floor (or floor mat) needed cleaning. If RTG is HIGH (>10<sup>7</sup> or 10<sup>9</sup> as appropriate) (with RTT <10<sup>7</sup> or 10<sup>9</sup> as appropriate) corrective action is needed. Floor mats can be evaluated for the problem using the same procedure as described for Worksurfaces above.

For ESD Floors, corrective action will depend on the nature of the floor (permanent flooring, ESD Floor Finish or ESD Paint).

Per ANSI/ESD S20.20 Table 3 Technical Requirements Flooring (Optional Element) Required Limit “less than 1 X 10<sup>9</sup> ohms measured per ANSI/ESD S7.1 or ESD TR53.

ANSI/ESD S7.1 section 5.3.1.6 “Perform a minimum of five tests per contiguous floor surface material or a minimum of five tests per 5,000 square feet (464.5 m2) of floor material, whichever is greater. A minimum of three of the five tests **should** be conducted in those areas that are subject to wear or that have chemical or water spillage or that are visibly dirty.” Dirt is typically insulative and a dissipative ESD protected floor cannot fulfil its function if covered by insulative material.

For Table 2 Personnel grounding Requirement Flooring – Footwear System Floor Materials and Footwear, Resistance Measurement in Combination with a Person less than 3.5 x 10<sup>7</sup> ohms measured per ESD STM 97.1” for Method 1 or Method 2 “less than 3.5 x 10<sup>9</sup> ohms measured per ESD STM 97.1” and “less than 100 Volts Floor Materials and Footwear-Voltage Measurement in Combination with a Person measured per ESD STM 97.2.”

**Chairs – RTG less than  $1 \times 10^9$  ohms if part of ESD program. Surfaces able to charge to 2,000 volts kept 12” from ESDS.**

Measurements noted if any. Chair RTG measured by using Resistance Meter. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb. electrode and place on various chair surfaces (seat, back rest, arms). Measured Resistance **must** be  $<10^9$  ohms.

If the chair is NOT considered part of the ESD Program, it is often helpful to rub the chair back and then take field measurement reading (See Insulators above). What we are looking for is if the back rest is capable of being charged to 2000 volts or greater.

Handbook ESD TR20.20 section 5.3.5.1 Introduction “Although not required in ANSI/ESD S20.20 as a primary means of grounding personnel in the workplace, the use of chairs that meet resistive requirements from the seat contact surface to the castors or leg ends, **may** be an effective means of grounding personnel if a reliable method can be found to bond personnel to the chair. In addition, if the chair is used to connect personnel to ground, then the maximum resistance to ground from the person through the chair and flooring system **should** be less than 35 megohms.”

Seating is an Optional Element within S20.20 Table 3 – EPA ESD Control Items. Required Limit is less than  $1 \times 10^9$  ohms as tested in accordance with ESD STM 12.1 or ESD TR53.

**Ionization - Process essential insulators neutralized with properly positioned & maintained ionizers or insulators kept 12” from ESDS. Out of balance less than +/-50 offset voltage.**

If ionization is used, measure both offset voltage (balance) and discharge times (both polarities + and -) using a Static Field Meter with an ION test kit attachment (ref: ESD SP3.3). If offset voltage or a discharge time is considered beyond acceptable limits, clean the ionizer pins (and filter if used) and re-test.

Offset voltage is a measure of the ionizer balance of positive and negative ion output. This can be adjusted if the ionizer is a DC type.

Discharge Time is a measurement of the ionizer’s ability to neutralize a charged object.

Report offset voltage, discharge times in seconds (+1,000 volts to +100 volts and -1,000 volts to -100 volts) and distance of the meter from the ionizer.

“Necessary non-conductors in the environment cannot lose their electrostatic charge by attachment to ground. Ionization systems provide neutralization of charges on these necessary non-conductive items (circuit board materials and some device packages are examples of necessary non-conductors). Assessment of the ESD hazard created by electrostatic charges on the necessary nonconductors in the work place is required to ensure that appropriate actions are implemented, commensurate with risk to ESDS items.” [ANSI/ESDS20.20 section Foreword]

Ionizers are an Optional Element within S20.20 Table 3 – EPA ESD Control Items

“In order to mitigate field-induced CDM [Charged Device Model] damage, the ESD program **shall** include a plan for the handling of process-required insulators. If the field exceeds 2,000 volts/inch, steps **shall** be taken to either:

A) Separate the insulator from the ESD-sensitive device by a distance of 30 cm (12 inches);

or

B) Use ionization or other charge mitigating techniques to neutralize the charge.” [ANSI/ESDS20.20 section 8.3]

Handbook ESD TR20.20 Ionization, Section 5.3.6.1 Introduction and Purpose / General Information “The primary method of static charge control is direct connection to ground for conductors, static dissipative materials, and personnel. A complete static control program **must** also deal with isolated conductors that cannot be grounded, insulating materials (e.g., most common plastics), and moving personnel who cannot use wrist or heel straps or ESD control flooring and footwear.

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

Per ESD TR 20.20 Handbook section 5.3 Protected Areas“ Necessary nonconductors **need** to be neutralized with ionized air if the static charge on them is determined to be a risk.”

Handbook ESD TR 20.20 section 5.3.6.6.5 Periodic Verification Testing “Simplified test methods for this purpose will be found in ESD SP3.3 – Periodic Verification of Air Ionizers. Ionizers **should** be tested for discharge time and balance after they have been installed in the use location. The time intervals for subsequent measurements will depend on the users requirements.”

Handbook ESD TR 20.20 section 5.3.6.7 Maintenance / Cleaning “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 uses 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 audit requirements.”

**Shelves electrically connected. RTG to be  $10^6$  to  $10^8$  ohms if storing unprotected ESDS items.**

Measure RTG of each shelf considered to be ESD Protective using resistance meter. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb. electrode and place on shelf. Measured Resistance **must** be  $<10^9$  ohms.

Shelving is an Optional Element within S20.20 Table 3 – EPA ESD Control Items. Required Limit is less than  $1 \times 10^9$  ohms tested per ANSI/ESD S4.1 or ESD TR53.

“If the shelving system is designed to store unpackaged ESD sensitive products, then it **should** be treated as an ESD worksurface. This means that the surface **must** be properly grounded, possess a [conductive] surface ... and be free of unnecessary static generators.” [ESD TR20.20 – Handbook section 5.3.7 Shelving] It is **recommended** that ESD worksurface have a resistance to ground [RTG] of  $1.0 \times 10^6$  to  $<1.0 \times 10^9$  ohms. [ESD S4.1 Worksurfaces section 8]

“All conductors in the environment, including personnel, **shall** be bonded or electrically connected and attached to a known ground”. [ANSI/ESDS20.20 section Foreword]

ANSI/ESD S20.20 Table 3 EPA Technical Requirements Required Limit, Shelving “less than  $1 \times 10^9$  ohms measured per ESD TR53 Worksurface Section”.

ESD Protected Workstations ESD-ADV53.1 Electrical Requirements, “Workstation elements **shall** be connected to, and maintain electrical continuity to, the common point ground as follows: Surfaces of shelves and drawers intended to be used for unprotected ESD sensitive devices - Resistance: Between  $1 \times 10^6$  ohms and  $1 \times 10^9$  ohms.”

**Carts grounded. RTG less than  $1 \times 10^9$  ohms. If storing unprotected ESDS cart shelves **should** be RTG  $10^6$  to  $10^8$  ohms.**

Measure RTG of each shelf considered to be ESD Protective using resistance meter. Connect one meter lead to ground using AC Outlet Analyzer. Connect the other meter lead to 5 lb. electrode and place on shelf. Measured Resistance **must** be  $<10^9$  ohms.

Mobile Equipment is an Optional Element within S20.20 Table 3 – EPA ESD Control Items. Required Limit for working surfaces is less than  $1 \times 10^9$  ohms tested per ANSI/ESD S4.1 or ESD TR53.

“Grounding / Equipotential Bonding Systems **shall** be used to ensure that ESDS items, personnel and any other conductors (e.g., mobile equipment) are at the same electrical potential.” [ANSI/ESDS20.20 section 8.1]

ESD Protected Workstations ESD-ADV53.1 Electrical Requirements, “Workstation elements **shall** be connected to, and maintain electrical continuity to, the common point ground as follows: Surfaces of shelves and drawers intended to be used for unprotected ESD sensitive devices - Resistance: Between  $1 \times 10^6$  ohms and  $1 \times 10^9$  ohms.”

**ESD Protective Smocks used to cover worker's synthetic clothing or kept 12" from ESDS. Groundable Static Control Garment System RTG less than  $1 \times 3.5 \times 10^7$  ohms. Smock **should** be grounded via cord or ESD footwear/floor.**

Measure via Wrist Strap / Footwear Tester or RTT sleeve-to-sleeve resistance by placing the garment on an insulative surface and placing a 5 lb. Electrode on each sleeve.

Garments are an Optional Element within S20.20 Table 3 – EPA ESD Control Items. Required Limit, Groundable Static Control Garment System RTG “less than  $1 \times 3.5 \times 10^7$  ohms measured per ESD TR53”, Groundable Static Control Garment “less than  $1 \times 10^9$  ohms”, or Static Control Garment “less than  $1 \times 10^{11}$  ohms”.

“In order to mitigate field-induced CDM [Charged Device Model] damage, the ESD program **shall** include a plan for the handling of process-required insulators. If the field exceeds 2,000 volts/inch ... separate the insulator from the ESD-sensitive device by a distance of 30 cm (12 inches)”; [ANSI/ESDS20.20 section 8.3]

Although ESD Smocks are not a S20.20 requirement, with regards to workers' clothing, it's a very effective means to comply with section 8.3.

Handbook ESD TR20.20 section 5.3.13.1 Introduction and Purpose/ General Information “While a person **may** be grounded using a wrist strap or other grounding methods, that does not mean that insulative clothing fabrics can dissipate a charge to that person's skin and then to ground. Clothing usually is electrically separate or isolated from the body.”

Handbook ESD TR20.20 section 5.3.13.2.6 Proper Use

“After verifying that the garment has electrical conductivity 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]. Garments **should** be worn with the front properly snapped or buttoned to avoid exposure of possible charges on personal clothing worn under the garment.”

Handbook ESD TR20.20 section 5.3.13.3.1.6 Labels “A label **should** be considered with the manufacturers name or logo and date or lot code and ESD identification. This will identify the smock as an ESD protective garment and provide information as to the manufacturer and date of manufacture. The label **should** be legible after 50 commercial cleanings (washings).”

**Solder Tips – AC Powered Tools < 1.0 ohm to ground per ESD DS 13.1**

Use multimeter (Fluke Multimeter) and measure path-to-ground to be less than 20 ohms. Connect one electrode to conductive end of powered tool (i.e. solder tip) and connect other electrode to equipment ground.

If solder iron is hot, use Soldering Tip Voltage Tester (such as Menda 35110) and verify proper grounding and low voltage.

Handbook ESD TR20.20 section 4.3.3.2 Tools and Equipment checklist includes: “4. Are soldering irons tested for tip to common point ground potential to prevent EOS [Electrical Over Stress] damage to components?”

ANSI/ESD S20.20-1999 Section 6.2.6.1. AC Powered Tools

The working part of AC powered tools **should** be capable of providing a conductive path to ground. New powered hand tools such as soldering irons typically **should** have a tip to ground resistance of less than 1.0 ohm. Note - This resistance may increase with use but **should** be less than 20.0 ohms for verification purposes.

“This hard ground is needed because the vast majority of soldering irons have some form of temperature control, either by switching the iron on or off at limits, or by using high-frequency effect. These control mechanisms can produce electric fields, and thus require a low impedance path to ground to prevent high potentials from being accumulated which can damage ESDS [ESD sensitive items].” [EN 61340-5-2 Section 5.2.10]

ANSI/ESD S20.20-1999 Section 6.2.6.2. Battery Powered and Pneumatic Hand Tools “Battery powered and pneumatic hand tools while being held **should** have a resistance to ground of less than  $1 \times 10^{12}$  ohms.”

## **SUMMARY**

An efficient and cost effective ESD Control program should be treated as an on-going process, like any good quality control system. As such, it should never be treated as an event.

All ESD Control costs should provide the user with improved quality (finished products that pass final test without rework) and increased reliability (fewer returned items and lower warranty costs). Through improved quality and reliability, the user should achieve a significant Return On Investment (ROI). One hi-tech company reported a 95:1 ROI for ESD Control. The range from other companies reported in articles is from 5:1 to 20:1.

Major companies state that 25% of all unidentified failure to electronics is a result of ESD. ElectroStatic charge generation increases significantly as relative humidity decreases; so typically if mysterious quality and reliability problems are observed in products manufactured during your lowest humidity season, it's likely ESD related. To maximize your ROI, highest loss operations, areas and products should be identified first. Then a corrective plan should be developed and evaluated. Once the corrective plan is determined, the ESD controls should be implemented and the resulting quality monitored. The effectiveness of the plan should then be evaluated and the plan refined if necessary. This process should be repeated as necessary until quality and reliability are at a level deemed acceptable to your company and customers.

By keeping ESD Control an on-going quality process, program costs and resulting ROI can be monitored so that the company can maximize total program value.

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