Fundamentals of Electrostatic Discharge

An Introduction to ESD

History & Background

To many people, static electricity is little more than the shock experienced when touching a metal doorknob after walking across a carpeted room or sliding across a car seat. However, static electricity has been a serious industrial problem for centuries. As early as the 1400's, European and Caribbean forts were using static control procedures and devices to prevent electrostatic discharge ignition of black powder stores. By the 1860's, paper mills throughout the U.S. employed basic grounding, flame ionization techniques, and steam drums to dissipate static electricity from the paper web as it traveled through the drying process.

The age of electronics brought with it new problems associated with static electricity and electrostatic discharge. And, as electronic devices became faster and smaller, their sensitivity to ESD increased. Today, ESD impacts productivity and product reliability in virtually every aspect of today's electronics environment. Many aspects of electrostatic control in the electronics industry also apply in other industries such as clean room applications and graphic arts.

Despite a great deal of effort during the past decade, ESD still affects production yields, manufacturing costs, product quality, product reliability, and profitability. Industry experts have estimated average product losses due to static to range from 8-33% (Table 1). Others estimate the actual cost of ESD damage to the electronics industry as running into the billions of dollars annually. The cost of damaged devices themselves ranges from only a few cents for a simple diode to several hundred dollars for complex hybrids. When associated costs of repair and rework, shipping, labor, and overhead are included, clearly the opportunities exist for significant improvements.

Table 1
Informal Summary of
Static Losses by Level

Static Losses Reported			
Description	Min. Loss	Max. Loss	Est. Avg. Loss
Component Manufacturers	4%	97%	16-22%
Subcontractors	3%	70%	9-15%
Contractors	2%	35%	8-14%

User	5%	70%	27-33%

This first in a series of six articles on the fundamentals of ESD and its control focuses on how electrostatic charge and discharge occur, how various materials affect the level of charge, types of ESD damage, and how ESD events can damage electronic components. Future articles will cover various ways to control the problem.

Static Electricity: Creating Charge

Static electricity is defined as an electrical charge caused by an imbalance of electrons on the surface of a material. This imbalance of electrons produces an electric field that can be measured and that can influence other objects at a distance. Electrostatic discharge is defined as the transfer of charge between bodies at different electrical potentials.

Electrostatic discharge can change the electrical characteristics of a semiconductor device, degrading or destroying it. Electrostatic discharge also may upset the normal operation of an electronic system, causing equipment malfunction or failure. Another problem caused by static electricity occurs in clean rooms. Charged surfaces can attract and hold contaminants, making removal from the environment difficult. When attracted to the surface of a silicon wafer or a device's electrical circuitry, these particulates can cause random wafer defects and reduce product yields.

Controlling electrostatic discharge begins with understanding how electrostatic charge occurs in the first place. Electrostatic charge is most commonly created by the contact and separation of two materials. For example, a person walking across the floor generates static electricity as shoe soles contact and then separate from the floor surface. An electronic device sliding into or out of a bag, magazine or tube generates an electrostatic charge as the device's housing and metal leads make multiple contacts and separations with the surface of the container. While the magnitude of electrostatic charge may be different in these examples, static electricity is indeed generated.

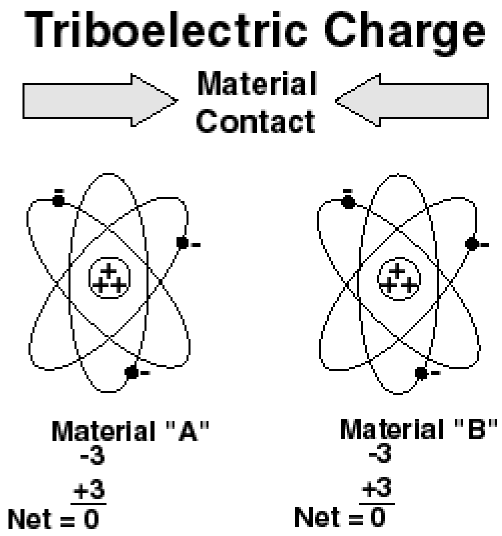

Figure 1 The Triboelectric Charge.
Materials Make Intimate Contact

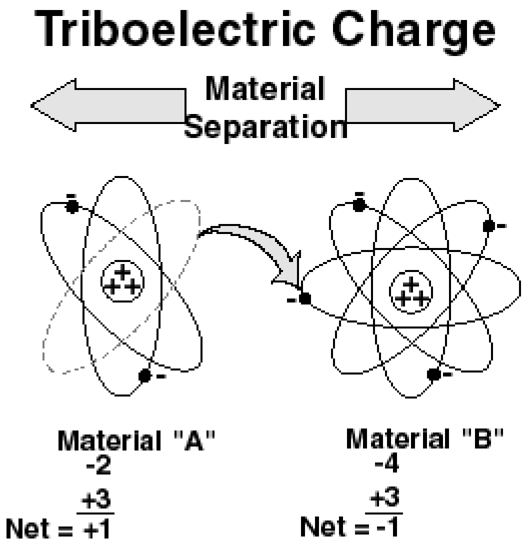

Figure 2 The Triboelectric Charge - Separation

Creating electrostatic charge by contact and separation of materials is known as "triboelectric charging." It involves the transfer of electrons between materials. The atoms of a material with no static charge have an equal number of positive (+) protons in their nucleus and negative (-) electrons orbiting the nucleus. In Figure 1, Material "A" consists of atoms with equal numbers of protons and electrons. Material B also consists of atoms with equal (though perhaps different) numbers of protons and electrons. Both materials are electrically neutral.

When the two materials are placed in contact and then separated, negatively charged electrons are transferred from the surface of one material to the surface of the other material. Which material loses electrons and which gains electrons will depend on the nature of the two materials. The material that loses electrons becomes positively charged, while the material that gains electrons is negatively charged. This is shown in Figure 2.

Static electricity is measured in coulombs. The charge "q" on an object is determined by the product of the capacitance of the object "C" and the voltage potential on the object (V):

$$q=CV$$

Commonly, however, we speak of the electrostatic potential on an object, which is expressed as voltage.

This process of material contact, electron transfer and separation is really a more complex mechanism than described here. The amount of charge created by triboelectric generation is affected by the area of contact, the speed of separation, relative humidity, and other factors. Once the charge is created on a material, it becomes an "electrostatic" charge (if it remains on the material). This charge may be transferred from the material, creating an electrostatic discharge, or ESD, event. Additional factors such as the resistance of the actual discharge circuit and the contact resistance at the interface between contacting surfaces also affect the actual charge that can cause damage.

Table 2
Examples of Static Generation
Typical Voltage Levels

Means of Generation	10-25% RH	65-90% RH
Walking across carpet	35,000V	1,500V
Walking across vinyl tile	12,000V	250V
Worker at bench	6,000V	100V
Poly bag picked up from bench	20,000V	1,200V
Chair with urethane foam	18,000V	1,500V

An electrostatic charge also may be created on a material in other ways such as by induction, ion bombardment, or contact with another charged object. However, triboelectric charging is the most common.

How Material Characteristics Affect Static Charge

Triboelectric Series

When two materials contact and separate, the polarity and magnitude of the charge are indicated by the materials' positions in the triboelectric series. The triboelectric series tables show how charges are generated on various materials. When two materials contact and separate, the one nearer the top of the series takes on a positive charge, the other a negative charge. Materials further apart on the table typically generate a higher charge than ones closer together. These tables, however, should only be used as a general guide because there are many variables involved that cannot be controlled well enough to ensure repeatability. A typical triboelectric series is shown in here.

Typical Triboelectric Series Rabbit Fur, Glass, Mica, Human Hair, Nylon, Wool, Fur, Lead, Silk, Aluminum, Paper, COTTON, Steel, Wood, Amber, Sealing Wax, Nickel, copper, Brass, silver, Gold, platinum, Sulfur, Acetate rayon, Polyester, Celluloid, Silicon, Teflon

Virtually all materials, including water and dirt particles in the air, can be triboelectrically charged. How much charge is generated, where that charge goes, and how quickly, are functions of the materials' electrical characteristics.

Insulative Materials

A material that prevents or limits the flow of electrons across its surface or through its volume is called an insulator. Insulators have an extremely high electrical resistance, generally greater than 1 x 10E12 ohms/sq (surface resistivity) and 1 x 10E11 ohm-cm (volume resistivity). A considerable amount of charge can be generated on the surface of an insulator. Because an insulative material does not readily allow the flow of electrons, both positive and negative charges can reside on insulative surface at the same time, although at different locations. The excess electrons at the negatively charged spot might be sufficient to satisfy the absence of electrons at the positively charged spot. However, electrons cannot easily flow across the insulative material's surface, and both charges may remain in place for a very long time.

Conductive Materials

A conductive material, because it has low electrical resistance, allows electrons to flow easily across its surface or through its volume. Conductive materials have low electrical resistance, generally less than 1 x 10E5 ohms/sq (surface resistivity) and 1 x 10E4 ohm-cm (volume resistivity). When a conductive material becomes charged, the charge (i.e., the deficiency or excess of electrons) will be uniformly distributed across the surface of the material. If the charged conductive material makes contact with another conductive material, the electrons will transfer between the materials quite easily. If the second conductor is attached to an earth grounding point, the electrons will flow to ground and the excess charge on the conductor will be "neutralized."

Electrostatic charge can be created triboelectrically on conductors the same way it is created on insulators. As long as the conductor is isolated from other conductors or ground, the static charge will remain on the conductor. If the conductor is grounded the charge will easily go to ground. Or, if the charged conductor contacts or nears another conductor, the charge will flow between the two conductors.

Static Dissipative Materials

Static dissipative materials have an electrical resistance between insulative and conductive materials (1 x 10E5 - 1 x 10E12 ohms/sq (surface resistivity) and 1 x 10E4 - 1 x 10E11 ohm-cm (volume resistivity). There can be electron flow across or through the dissipative material, but it is controlled by the surface resistance or volume resistance of the material.

As with the other two types of materials, charge can be generated triboelectrically on a static dissipative material. However, like the conductive material, the static dissipative material will allow the transfer of charge to ground or other conductive objects. The transfer of charge from a static dissipative material will generally take longer than from a conductive material of equivalent size. Charge transfers from static dissipative materials are significantly faster than from insulators, and slower than from conductors.

Electrostatic Fields

Charged materials also have an electrostatic field and lines of force associated with them. Conductive objects brought into the vicinity of this electric field will be polarized by a process known as induction. A negative electric field will repel electrons on the surface of the conducting item that is exposed to the field. A positive electric field will attract electrons to near the surface thus leaving other areas positively charged. No change in the actual charge on the item will occur in polarization. If, however, the item is conductive or dissipative and is touched to ground while polarized, charge will flow from or to ground to compensate for the charge imbalance. If the electrostatic field is removed and the ground contact disconnected, the charge will be trapped on the item. If a nonconductive object is brought into the electric field, the electrical dipoles will tend to align with the field creating apparent surface charges. A nonconductor cannot be charged by induction.

ESD Damage-How Devices Fail

Electrostatic damage to electronic devices can occur at any point from manufacture to field service. Damage results from handling the devices in uncontrolled surroundings or when poor ESD control practices are used. Generally damage is classified as either a catastrophic failure or a latent defect.

Catastrophic Failure

When an electronic device is exposed to an ESD event, it may no longer function. The ESD event may have caused a metal melt, junction breakdown, or oxide failure. The device's circuitry is permanently damaged causing the device fail. Such failures usually can be detected when the device is tested before shipment. If the ESD event occurs after test, the damage will go undetected until the device fails in operation.

Latent Defect

A latent defect, on the other hand, is more difficult to identify. A device that is exposed to an ESD event may be partially degraded, yet continue to perform its intended function. However, the operating life of the device may be reduced dramatically. A product or system incorporating devices with latent defects may experience premature failure after the user places them in service. Such failures are usually costly to repair and in some applications may create personnel hazards.

It is relatively easy with the proper equipment to confirm that a device has experienced catastrophic failure. Basic performance tests will substantiate device damage. However, latent defects are extremely difficult to prove or detect using current technology, especially after the device is assembled into a finished product.

Basic ESD Events--What Causes Electronic Devices to Fail?

ESD damage is usually caused by one of three events: direct electrostatic discharge to the device, electrostatic discharge from the device or field-induced discharges. Damage to an ESDS device by the ESD event is determined by the device's ability to dissipate the energy of the discharge or withstand the voltage levels involved. This is known as the device's "ESD sensitivity.

Discharge to the Device

An ESD event can occur when any charged conductor (including the human body) discharges to an ESDS (electrostatic discharge sensitive) device. The most common cause of electrostatic damage is the direct transfer of electrostatic charge from the human body or a charged material to the electrostatic discharge sensitive (ESDS) device. When one walks across a floor, an electrostatic charge accumulates on the body. Simple contact of a finger to the leads of an ESDS device or assembly allows the body to discharge, possibly causing device damage. The model used to simulate this event is the Human Body Model (HBM). A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture. The model used to characterize this event is known as the Machine Model.

Discharge from the Device

The transfer of charge from an ESDS device is also an ESD event. Static charge may accumulate on the ESDS device itself through handling or contact with packaging materials, worksurfaces, or machine surfaces. This frequently occurs when a device moves across a surface or vibrates in a package. The model used to simulate the transfer of charge from an ESDS device is referred to as the Charged Device Model (CDM). The capacitance and energies involved are different from those of a discharge to the ESDS device. In some cases, a CDM event can be more destructive than the HBM for some devices.

The trend towards automated assembly would seem to solve the problems of HBM ESD events. However, it has been shown that components may be more sensitive to damage when assembled by automated equipment. A device may become charged, for example, from sliding down the feeder. If it then contacts the insertion head or another conductive surface, a rapid discharge occurs from the device to the metal object.

Field Induced Discharges

Another event that can directly or indirectly damage devices is termed Field Induction. As noted earlier, whenever any object becomes electrostatically charged, there is an electrostatic field associated with that charge. If an ESDS device is placed in that electrostatic field, a charge may be induced on the device. If the device is then momentarily grounded while within the electrostatic field, a transfer of charge from the device occurs as a CDM event. If the device is removed from the region of the electrostatic field and grounded again, a second CDM event will occur as charge (of opposite polarity from the first event) is transferred from the device.

How Much Static Protection is Needed?

As noted earlier, damage to an ESDS device by the ESD event is determined by the device's ability to dissipate the energy of the discharge or withstand the voltage levels involved-its ESD sensitivity. Defining the ESD sensitivity of electronic components is the first step in determining the degree of ESD protection required. Test procedures based on the models of ESD events help define the sensitivity of components to ESD. These procedures will be covered in a future article in this series.

Many electronic components are susceptible to ESD damage at relatively low voltage levels. Many are susceptible at less than 100 volts, and many disk drive components have sensitivities below 10 volts. Current trends in product design and development pack more circuitry onto these miniature devices, further increasing their sensitivity to ESD and making the potential problem even more acute. Tables 4 and 5 indicate the ESD sensitivity of various types of components.

Table 4 **ESD Sensitivity of Representative Electronic DevicesDevices or Parts with Sensitivity Levels of 0-1,999 volts (HBM)**
Device or Part Type
Microwave devices (Schottky barrier diodes, point contact diodes and other detector diodes >1 GHz)
Discrete MOSFET devices
Surface acoustic wave (SAW) devices
Junction field effect transistors (JFETs)
Charged coupled devices (CCDs)
Precision voltage regulator diodes (line of load voltage regulation, <0.5%)
Operational amplifiers (OP AMPs)
Thin film resistors
Integrated circuits
AMR and GMR Disk Drive Recording Heads
Laser Diodes
Hybrids
Very high speed integrated circuits (VHSIC)
Silicon controlled rectifiers (SCRs) with Io <0.175 amp at 10°C ambient 10

Table 5 **ESD Sensitivity of Representative Electronic DevicesDevices or Parts with Sensitivity Levels of 2,000 to 3,999 volts (HBM)**
Device or Part Type

Discrete MOSFET devices
JFETs
Operational Amplifiers (OP Amps
Integrated circuits (ICs)
Very high speed integrated circuits (VHSIC)
Precision resistor networks (type RZ)
Hybrids
Low power bipolar transistors, PT £100 milliwatts with Ic <100 milliamps

Summary

In this introductory article on electrostatic discharge, we have discussed the basics of electrostatic charge and discharge, types of failures, ESD events, and device sensitivity. We can summarize this discussion as follows:

1. Virtually all materials, even conductors, can be triboelectrically charged.

2. The level of charge is affected by material type, speed of contact and separation, humidity, and several other factors.

3. Electrostatic fields are associated with charged objects.

4. Electrostatic discharge can damage devices so they fail immediately, or ESD may result in latent damage that may escape immediate attention, but cause the device to fail prematurely once in service.

5. Electrostatic discharge can occur throughout the manufacturing, test, shipping, handling, or operational processes.

6. Component damage can occur as the result of a discharge to the device, from the device, or from charge transfers resulting from electrostatic fields. Devices vary significantly in their sensitivity to ESD.

Principles of ESD Control

In our previous article, Introduction to Electrostatic Discharge, we discussed the basics of electrostatic charge, discharge, types of failures, ESD events, and device sensitivity. We concluded our discussion with the following summary:

1. Virtually all materials, even conductors, can be triboelectrically charged.

2. The level of charge is affected by material type, speed of contact and separation, humidity, and several other factors.

3. Electrostatic fields are associated with charged objects.

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5. Electrostatic discharge can occur throughout the manufacturing, test, shipping, handling, or operational processes.

6. Component damage can occur as the result of a discharge to the device, from the device, or from charge transfers resulting from electrostatic fields. Devices vary significantly in their sensitivity to ESD.

Understanding these key concepts is crucial to protecting your products from the effects of static damage. Armed with this information, you can then begin to develop an effective ESD control program. In Part Two we will focus on some basic concepts of ESD control.

Basic Principles of Static Control

Sometimes, controlling electrostatic discharge (ESD) in the electronics environment seems to be a formidable challenge. However, the task of designing and implementing ESD control programs becomes less complex if we focus on just six basic principles of control. In doing so, we also need to keep in mind the ESD corollary to Murphy's law, "no matter what we do, static charge will try to find a way to discharge."

1. Design In Immunity

The first Principle is to design products and assemblies to be as immune as reasonable from the effects of ESD. This involves such steps as using less static sensitive devices or providing appropriate input protection on devices, boards, assemblies, and equipment. For engineers and designers, the paradox is that advancing product technology requires smaller and more complex geometries that often are more susceptible to ESD.

2. Define the level of control needed in your environment.

What is the sensitivity level of the parts you are using and the products that you are manufacturing and shipping? ANSI/ESD S 20.20 defines a control program for items that are sensitive to 100 volts Human Body Model (HBM). Your environment may be different.

3. Identify and define the electrostatic protected areas (EPA).

These are the areas in which you will be handling sensitive parts and the areas in which you will need to bond or electrically connect all conductive and dissipative materials, including personnel, to a known ground.

4. Eliminate and Reduce Generation

Obviously, product design isn't the whole answer. The fourth Principle of control is to eliminate or reduce the generation and accumulation of electrostatic charge in the first place. It's fairly basic: no charge -- no discharge. We begin by reducing as many static generating processes or materials, such as the contact and separation of dissimilar materials and common plastics, as possible from the work environment. We keep other processes and materials at the same electrostatic potential. Electrostatic discharge does not occur between materials kept at the same potential or at zero potential. We provide ground paths, such as wrist straps, flooring and work surfaces, to reduce charge generation and accumulation.

5. Dissipate and Neutralize

Because we simply can"t eliminate all generation of static in the environment, our fifth Principle is to safely dissipate or neutralize those electrostatic charges that do occur. Proper grounding and the use of conductive or dissipative materials play major roles. For example, workers who "carry" a charge into the work environment can rid themselves of that charge when they attach a wrist strap or when they step on an ESD floor mat while wearing ESD control footwear. The charge goes to ground rather than being discharged into a sensitive part. To prevent damaging a charged device, the rate of discharge can be controlled with static dissipative materials.

For some objects, such as common plastics and other insulators, grounding does not remove an electrostatic charge because there is no conductive pathway. Typically, ionization is used to neutralize charges on these insulating materials. The ionization process generates negative and positive ions that are attracted to the surface of a charged object, thereby effectively neutralizing the charge.

6. Protect Products

Our final ESD control Principle is to prevent discharges that do occur from reaching susceptible parts and assemblies. One way is to provide our parts and assemblies with proper grounding or shunting that will dissipate any discharge away from the product. A second method is to package and transport susceptible devices in proper packaging and materials handling products. These materials may effectively shield the product from charge, as well as reduce the generation of charge caused by any movement of product within the container.

Elements of an Effective ESD Control Program

While these six principles may seem rather basic, they can guide us in the selection of appropriate materials and procedures to use in effectively controlling ESD. In most circumstances, effective programs will involve all of these principles. No single procedure or product will do the whole job; rather effective static control requires a full ESD control program.

How to we develop and maintain a program that puts these basic principles into practice? How do we start? What is the process? What do we do first? Ask a dozen experts and you may get a dozen different answers. But, if you dig a little deeper, you will find that most of the answers center on similar key elements. You will also find that starting and maintaining an ESD control program is similar to many other business activities and projects. Although each company is unique in terms of its ESD control needs, there are at least 6 critical elements to successfully developing and implementing an effective ESD control program.

1. Establish an ESD Coordinator and ESD Teams.

As the problem-solving style of the decade, the team approach particularly applies to ESD because the problems and the solutions cross various functions, departments, divisions and even suppliers in most companies. Team composition includes line employees as well as department heads or other management personnel. ESD teams or committees help assure a variety of viewpoints, the availability of the needed expertise, and commitment to success. An active ESD committee helps unify the effort and brings additional expertise to the project. Committee or team membership should include representation from areas such as engineering, manufacturing, field service, training, and quality.

Heading this team effort is an ESD Program Coordinator. Ideally this responsibility should be a full-time job. However, we seldom operate in an ideal environment and you may have to settle for the function to be a major responsibility of an individual. The ESD coordinator is responsible for developing, budgeting, and administering the program. The coordinator also serves as the company's internal ESD consultant to all areas.

2. Assess Your Organization, Facility, Processes and Losses

Your next step is to gain a thorough understanding of your environment and its impact on ESD. Armed with your loss and sensitivity data, you can evaluate your facility, looking for areas and procedures that may be contributing to your defined ESD problems. Be on the lookout for things such as static generating materials and personnel handling procedures for ESD-sensitive items.

Document your processes. Observe the movement of people and materials through the areas. Note those areas that would appear to have the greatest potential for ESD problems. Remember, that ESD can occur in the warehouse just as it can in the assembly areas. Then conduct a thorough facility survey or audit. Measure personnel, equipment, and materials to identify the presence of electrostatic fields in your environment.

Before seeking solutions to your problems, you will need to determine the extent of your losses to ESD. These losses may be reflected in receiving reports, QA and QC records, customer returns, in-plant yields, failure analysis reports, and other data that you may already have or that you need to gather. This information not only identifies the magnitude of the problem, but also helps to pinpoint and prioritize areas that need attention.

Document your actual and potential ESD losses in terms of DOA components, rework, customer returns, and failures during final test and inspection. Use data from outside sources or the results of your pilot program for additional support. Develop estimates of the savings to be realized from implementing an ESD control program.

You will also want to identify those items (components, assemblies, and finished products) that are sensitive to ESD and the level of their sensitivity. You can test these items yourself, use data from suppliers, or rely on published data for similar items.

3. Establish and Document Your ESD Control Program Plan

After completing your assessment, you can begin to develop and document your ESD control program plan. The plan should cover the scope of the program and include the tasks, activities and procedures necessary to protect the ESD sensitive items at or above the ESD sensitivity level chosen for the plan. Prepare and distribute written procedures and specifications so that everyone has a clear understanding of what is to be done. Fully documented procedures will help you meet the administrative and technical elements of ANSI ESD S20.20 and help you with ISO 9000 certification as well.

4. Build Justification to Get the Management Support Top Management

To be successful, an ESD program requires the support of your top management, at the highest level possible. What level of commitment is required? To obtain commitment, you will need to build justification for the plan. You will need to emphasize quality and reliability, the costs of ESD damage, the impact of ESD on customer service and product performance. You may even need to conduct a pilot program if the experience of other companies is not sufficient to help prove your point.

Prepare a short corporate policy statement on ESD control. Have top management co-sign it with the ESD coordinator. Periodically, reaffirm the policy statement and management's commitment to it.

5. Define A Training Plan

Train and retrain your personnel in ESD and your company's ESD control program and procedures. Proper training for line personnel is especially important. They are often the ones who have to live with the procedures on a day-to-day basis. A sustained commitment and mindset among all employees that ESD prevention is a valuable, on-going effort by everyone is one of the primary goals of training.

6. Develop and Implement a Compliance Verification Plan

Developing and implementing the program itself is obvious. What might not be so obvious is the need to continually review, audit, analyze, feedback and improve. Auditing is essential to ensure that the ESD control program is successful. You will be asked to continually identify the return on investment of the program and to justify the savings realized. Technological changes will dictate improvements and modifications. Feedback to employees and top management is essential. Management commitment will need reinforcement.

Include both reporting and feedback to management, the ESD team, and other employees as part of your plan. Management will want to know that their investment in time and money is yielding a return in terms of quality, reliability and profits. Team members need a pat on the back for a job well done. Other employees will want to know that the procedures you have asked them to follow are indeed worthwhile.

Conduct periodic evaluations of your program and audits of your facility. You will find out if your program is successful and is giving you the expected return. You will spot weaknesses in the program and shore them up. You will discover whether the procedures are being followed.

As you find areas that need work, be sure to make the necessary adjustments to keep the program on track.

Conclusion

Six principles of static control and six key elements to program development and implementation: your guideposts for effective ESD control programs. In the next column, we'll take a close look at specific procedures and materials that become part of your program.

Basic ESD Control Procedures and Materials

In Part Two---Principles of ESD Control, we introduced four principles of static control and nine key elements of ESD program development and implementation. In Part Three, we will cover some of the primary specific static control procedures and materials that become part of your program. First, a quick review.

Basic Principles of Static Control

We suggested focusing on just six basic principles in the development and implementation of effective ESD control programs:

1. Design in immunity by designing products and assemblies to be as immune as reasonable from the effects of ESD.
2. Define the level of control needed in your environment.
3. Identify and define the electrostatic protected areas (EPA), the areas in which you will be handling sensitive parts.
4. Eliminate and reduce generation by reducing and eliminating static generating processes, keeping processes and materials at the same electrostatic potential, and by providing appropriate ground paths to reduce charge generation and accumulation.
5. Dissipate and neutralize by grounding, ionization, and the use of conductive and dissipative static control materials.
6. Protect products from ESD with proper grounding or shunting and the use of static control packaging and materials handling products.

At the facility level our static control efforts concentrate on the last five principles. In this column we will concentrate on the primary materials and procedures that eliminate and reduce generation, dissipate and neutralize charges, or protect sensitive products from ESD.

Identifying the Problem Areas and the Level of Control

One of the first questions we need to answer is "How sensitive are the parts and assemblies we are manufacturing or handling?" This information will guide you in determining the various procedures and materials required to control ESD in your environment.

How do you determine the sensitivity of your parts and assemblies or where can you get information about their ESD sensitivity? A first source would be the manufacturer or supplier of the component itself. An additional source is ITT Research Institute/Reliability Analysis Center in Rome, NY, which publishes ESD susceptibility data for 22,000 devices, including microcircuits. You may find that you need to have your specific parts tested for ESD sensitivity. We will discuss device sensitivity testing in part 5 of this series.

The second question you need to answer is "Which areas of our facility need ESD protection?" This will allow to define your specific electrostatic protected areas (EPAs), the areas in which you will be handling sensitive parts and the areas in which you will need to bond or electrically connect all conductive and dissipative materials, including personnel, to a known ground. Often you will find that there are more areas that require protection than you originally thought, usually wherever ESDS devices are handled. Typical areas requiring ESD protection are shown in Table 1.

Table 1 Typical Facility Areas Requiring ESD Protection
Receiving
Inspection
Stores and warehouses
Assembly
Test and inspection
Research and development
Packaging

Field service repair
Offices and laboratories
Clean rooms

Grounding

Throughout our discussion, we will see how important grounding is to effective ESD control. Effective ESD grounds are of critical importance in any operation, and ESD grounding should be clearly defined and regularly evaluated.

A primary means of protecting of ESD susceptible (ESDS) items is to provide a ground path to bring ESD protective materials and personnel to the same electrical potential. All conductors in the environment, including personnel, must be bonded or electrically connected and attached to a known ground or contrived ground, creating an equipotential balance between all items and personnel. Electrostatic protection can be maintained at a potential above a "zero" voltage ground reference as long as all items in the system are at the same potential. It is important to note that non-conductors in an Electrostatic Protected Area (EPA) cannot lose their electrostatic charge by attachment to ground

ESD Association Standard ANSI EOS/ESD 6.1-Grounding recommends a two-step procedure for grounding ESD protective equipment.

The first step is to ground all components of the work area (worksurfaces, people, equipment, etc.) to the same electrical ground point called the "common point ground." This common point ground is defined as a "system or method for connecting two or more grounding conductors to the same electrical potential."

Figure 2--Common Point Ground Symbol

This ESD common point ground should be properly identified. ESD Association standard EOS/ESD S8.1 recommends the use of the symbol in Figure 2 to identify the common point ground.

The second step is to connect the common point ground to the equipment ground or the third wire (green) electrical ground connection. This is the preferred ground connection because all electrical equipment at the workstation is already connected to this ground. Connecting the ESD control materials or equipment to the equipment ground brings all components of the workstation to the same electrical potential. If a soldering iron used to repair an ESDS item were connected to the electrical ground and the surface containing the ESDS item were connected to an auxiliary ground, a difference in electrical potential could exist between the iron and the ESDS item. This difference in potential could cause damage to the item.

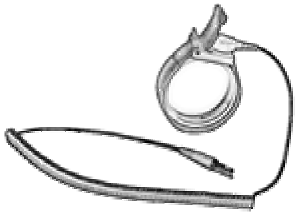
Any auxiliary grounds (water pipe, building frame, ground stake) present and used at the workstation must be bonded to the equipment ground to minimize differences in potential between the two grounds.

Detailed information on ESD grounding can be found in ESD Association standard ESD-S6.1, Grounding-Recommended Practices.

Controlling Static on Personnel and Moving Equipment

In many facilities, people are one of the prime generators of static electricity. The simple act of walking around or repairing a board can generate several thousand volts on the human body. If not properly controlled, this static charge can easily discharge into a static sensitive device—a human body model (HBM) discharge.

Even in highly automated assembly and test processes, people still handle static sensitive devices--in the warehouse, in repair, in the lab, in transport. For this reason, static control programs place considerable emphasis on controlling personnel generated electrostatic discharge. Similarly, the movement of carts and other wheeled equipment through the facility also can generate static charges that can transfer to the products being transported on this equipment.



Wrist Straps

Typically, wrist straps are the primary means of controlling static charge on personnel. When properly worn and connected to ground, a wrist strap keeps the person wearing it near ground potential. Because the person and other grounded objects in the work area are at or near the same potential, there can be no hazardous discharge between them. In addition, static charges are safely dissipated from the person to ground and do not accumulate.

Wrist straps have two major components, the cuff that goes around the person's wrist and the ground cord that connects the cuff to the common point ground. Most wrist straps have a current limiting resistor molded into the ground cord head on the end that connects to the cuff. The resistor most commonly used is a one megohm, 1/4 watt with a working voltage rating of 250 volts.

Wrist straps should be tested on a regular basis. Daily testing or continuous monitoring is recommended.

Floors, Floor Mats, Floor Finishes

A second method of controlling electrostatic charge on personnel is with the use of ESD protective floors in conjunction with ESD control footwear or foot straps. This combination of floor materials and footwear provides a ground path for the dissipation of electrostatic charge, thus reducing the charge accumulation on personnel and other objects to safe levels. In addition to dissipating charge, some floor materials (and floor finishes) also reduce triboelectric charging. The use of floor materials is especially appropriate in those areas where increased personnel mobility is necessary. In addition, floor materials can minimize charge accumulation on chairs, carts, lift trucks and other objects that move across the floor. However, those items require dissipative or conductive casters or wheels to make electrical contact with the floor. When used as the primary personnel grounding system, the resistance to ground including the person, footwear and floor must be the same as specified for wrist straps (< 35 x 10E6 ohms) or the voltage accumulation on a person must be less than 100 volts.

Shoes, Grounders, Casters

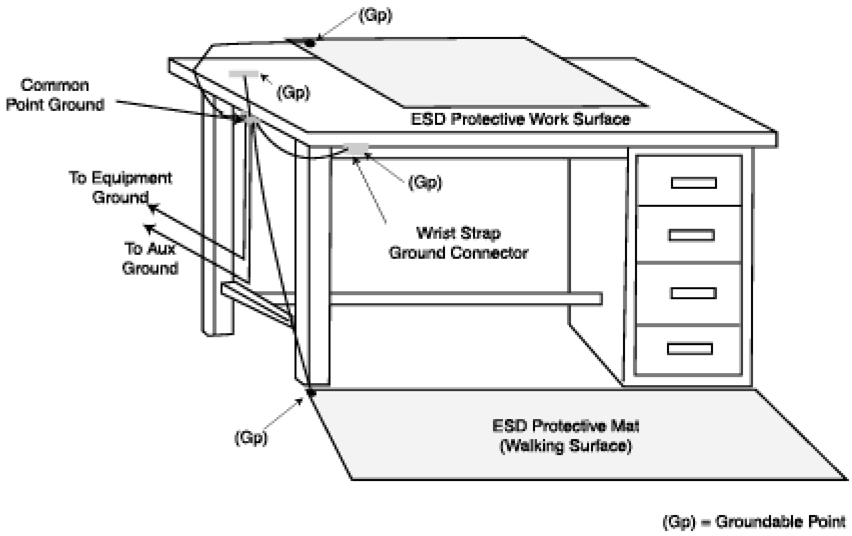
Used in combination with ESD protective floor materials, static control shoes, grounders, casters and wheels provide the necessary electrical contact between the person or object and the floor material. Insulative footwear, casters, or wheels prevent static charges from flowing from the body to the floor to ground.

Clothing

Clothing is a consideration in some ESD protective areas, especially in clean rooms and very dry environments. Clothing materials can generate electrostatic charges that may discharge into sensitive components or they may create electrostatic fields that may induce charges on the human body. Because clothing usually is electrically insulated or isolated from the body, charges on clothing fabrics are not necessarily dissipated to the skin and then to ground. Grounded static control garments are intended to minimize the effects of electrostatic fields or charges that may be present on a person's clothing.

Workstations and Worksurfaces

Figure 1--Typical ESD Workstation



An ESD protective workstation refers to the work area of a single individual that is constructed and equipped with materials and equipment to limit damage to ESD sensitive items. It may be a stand-alone station in a stockroom, warehouse, or assembly area, or in a field location such as a computer bay in commercial aircraft. A workstation also may be located in a controlled area such as a clean room. The key ESD control elements comprising most workstations are a static dissipative worksurface, a means of grounding personnel (usually a wrist strap), a common grounding connection, and appropriate signage and labeling. A typical workstation is shown in Figure 3.

The workstation provides a means for connecting all worksurfaces, fixtures, handling equipment, and grounding devices to a common point ground. In addition, there may be provision for connecting additional personal grounding devices, equipment, and accessories such as constant ground monitors and ionizers.

Static protective worksurfaces with a resistance to ground of 10E6 to 10E9 provide a surface that is at the same electrical potential as other ESD protective items in the workstation. They also provide an electrical path to ground for the controlled dissipation of any static potentials on materials that contact the surface. The worksurface also helps define a specific work area in which ESD sensitive devices may be safely handled. The worksurface is connected to the common point ground.

Production Equipment and Production Aids

Although personnel generated static is usually the primary ESD culprit in many environments, automated manufacturing and test equipment also can pose an ESD problem. For example, a device may become charged from sliding down a feeder. If the device then contacts the insertion head or another conductive surface, a rapid discharge occurs from the device to the metal object--a Charged Device Model (CDM) event. In addition, various production aids such as hand tools, tapes, or solvents also be ESD concerns.

Grounding is the primary means of controlling static charge on equipment and many production aids. Much electrical equipment is required by the National Electrical Code to be connected to the equipment ground (the green wire) in order to carry fault currents. This ground connection also will function for ESD purposes. All electrical tools and equipment used to process ESD sensitive hardware require the 3 prong grounded type AC plug. Hand tools that are not electrically powered, i.e., pliers, wire cutters, and tweezers, are usually grounded through the ESD worksurface and the (grounded) person using the conductive tools. Holding fixtures should be made of conductive or static dissipative materials when possible. A separate ground wire may be required for conductive fixtures not sitting on an ESD worksurface or handled by a grounded person. For those items that are composed of insulative materials, the use of ionization or application of topical antistats may be required to control generation and accumulation of static charges.

Packaging and Handling

Direct protection of ESDS devices from electrostatic discharge is provided by packaging materials such as bags, corrugated, and rigid or semi-rigid packages. The primary use of these items is to protect the product when it leaves the facility, usually when shipped to a customer. In addition, materials handling products such as tote boxes and other containers primarily provide protection during inter or intra facility transport.

The main ESD function of these packaging and materials handling products is to limit the possible impact of ESD from triboelectric charge generation, direct discharge, and electrostatic fields. The initial consideration is to have low charging materials in contact with ESD sensitive items. For example, the low charging property would control triboelectric charge resulting from sliding a board or component into the package or container. A second requirement is that the material provides protection from direct electrostatic discharge as well as shield from electrostatic fields.

Many materials are available that provide all three benefits: low charging, discharge protection, and electric field suppression. The inside of these packaging materials have a low charging layer, but also have an outer layer with a surface resistance generally in the dissipative range.

Resistance or resistivity measurements help define the material's ability to provide electrostatic shielding or charge dissipation. Electrostatic shielding attenuates electrostatic fields on the surface of a package in order to prevent a difference in electrical potential from existing inside the package. Electrostatic shielding is provided by materials that have a surface resistance equal to or less than 1.0 x 10E3 when tested according to EOS/ESD-S11.11 or a volume resistivity of equal to or less than 1.0 x 10E3 ohm-cm when tested according to the methods of EIA 541. In addition, shielding may be provided by packaging materials that provide an air gap between the package and the product. Dissipative materials provide charge dissipation characteristics. These materials have a surface resistance greater than 1.0 x 10E4 but less than or equal to 1.0 x 10E11 when tested according to EOS/ESD-S11.11 or a volume resistivity greater than 1.0 x 10E5 ohm-cm but less than or equal to 1.0 x 10E12 ohm-cm when tested according to the methods of EIA 541. ANSI/ESD 11.31 also is used to evaluate the shielding characteristics of bags.

A material's low charging properties are not necessarily predicted by its resistance or resistivity.

Ionization

However, most static control programs also deal with isolated conductors that cannot be grounded, insulating materials (e.g., most common plastics). Topical antistats often are used to dissipate static charges from these items under some circumstances

More frequently, however, 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 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 one component of a complete static control program, not necessarily a substitute for grounding or other methods. 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.

Cleanrooms

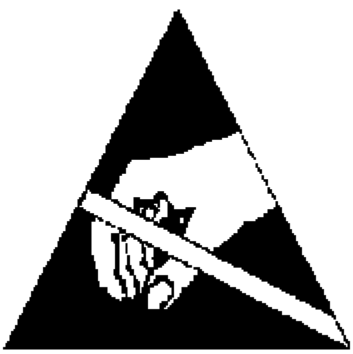
While the basic methods of static control discussed here are applicable in most environments, cleanroom manufacturing processes require special considerations.

Many objects integral to the semiconductor manufacturing process (quartz, glass, plastic, and ceramic) are inherently charge generating. Because these materials are insulators, this charge cannot be removed easily by grounding. Many static control materials contain carbon particles or surfactant additives that sometimes restrict their use in clean rooms. The need for personnel mobility and the use of clean room garments often make the use of wrist straps difficult. In these circumstances, ionization and flooring/footwear systems become key weapons against static charge.

Identification

A final element in our static control program is the use of appropriate symbols to identify static sensitive devices and assemblies, as well as products intended to control ESD. The two most widely accepted symbols for identifying ESDS parts or ESD control materials are defined in ESD Association Standard ANSI ESD S8.1-1993 — ESD Awareness Symbols.

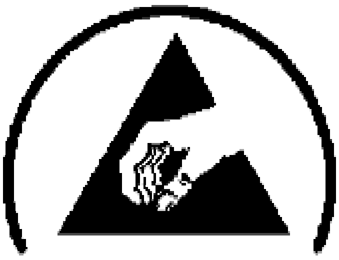
Figure 3--ESD Susceptibility Symbol



The ESD Susceptibility Symbol (Figure 3) consists of a triangle, a reaching hand, and a slash through the reaching hand. The triangle means "caution" and the slash through the reaching hand means "Don't touch." Because of its broad usage, the hand in the triangle has become associated with ESD and the symbol literally translates to "ESD sensitive stuff, don't touch."

The ESD Susceptibility Symbol is applied directly to integrated circuits, boards, and assemblies that are static sensitive. It indicates that handling or use of this item may result in damage from ESD if proper precautions are not taken. If desired, the sensitivity level of the item may be added to the label.

Figure 4-- ESD Protective Symbol



The ESD Protective Symbol (Figure 4) consists of the reaching hand in the triangle. An arc around the triangle replaces the slash. This "umbrella" means protection. The symbol indicates ESD protective material. It is applied to mats, chairs, wrist straps, garments, packaging, and other items that provide ESD protection. It also may be used on equipment such as hand tools, conveyor belts, or automated handlers that is especially designed or modified to provide ESD control.

Neither symbol is applied on ESD test equipment, footwear checkers, wrist strap testers, resistance or resistivity meters or similar items that are used for ESD purposes, but which do not provide actual protection.

Summary

Effective static control programs require a variety of procedures and materials. In this column, we have provided a brief overview of the most commonly used elements of a program. Additional in-depth discussion of individual materials and procedures can be found in publications such as the ESD Handbook published by the ESD Association.

Auditing and Training

Your static control program is up and running. How do you determine whether it is effective? How do you make sure your employees follow it? Previously, we suggested that there were at least nine critical elements to successfully developing and implementing an effective ESD control program. In Part Four, we will focus on two more of these elements: training and auditing.

Personnel Training

The procedures are in place. The materials are in use. But, your ESD control program just does not seem to yield the expected results. Failures declined initially, but they have begun reversing direction. Or perhaps there was little improvement at all. The solutions might not be apparent in inspection reports of incoming ESD materials. Nor in the wrist strap log-in sheets. In large companies or small, it is hard to underestimate the role of training in an ESD control program. The new ANSI/ESD S20.20 ESD Control Program standard cites training as a basic administrative requirement of an ESD control program. There is significant evidence to support the contribution of training to the success of the program (References 2, 11, 18, 19, 23, 24). We would not send employees to the factory floor without the proper soldering skills or the knowledge to operate the automated insertion equipment. We should provide them with the same skill level regarding ESD control procedures.

Elements of Effective Training Programs

Although individual requirements cause training programs to vary from company to company, there are several common threads that run through the successful programs.

1 -- Successful training programs cover all affected employees.

Obviously we train the line employees who test their wrist straps or place finished products in static protective packaging. But we also include department heads, upper management, and executive personnel in the process. Typically they are responsible for the day-to-day supervision and administration of the program or they provide leadership and support. Even subcontractors and suppliers should be considered for inclusion in the training program.

Because ESD control programs cover such a variety of job disciplines and educational levels, it may be necessary to develop special training modules for each organizational entity. For example, the modules developed for management, engineering, technicians and field service could differ significantly because their day-to-day concerns and responsibilities are much different.

2 -- Effective training is comprehensive and consistent.

Training not only covers specific procedures, but also the physics of the problem and the benefits of the program as well. Consistent content across various groups, plants, and even countries (adjusted for cultural differences, of course) reduces confusion and helps assure conformance. The training content should include topics such as the fundamentals of ESD, the details of the organization's ESD Control Program plan, and each person's role in the plan.

3 -- Use a variety of training tools and techniques.

Choose the methods that will work best for your organization. Combine live instruction with training videos or interactive CD-ROM programs. You may have in-house instructors available, or you may need to go outside the company to find instructors or training materials. You can also integrate industry symposia, tutorials, and workshops into your program.

Effective training involves employees in the process. Reinforce the message with demonstrations of ESD events and their impact. Bulletin boards, newsletters, and posters provide additional reminders and reinforcement.

Maintaining a central repository for educational ESD control materials will help your employees keep current or answer questions that may occur outside the formal training sessions. Materials in such a 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

In addition, a knowledgeable person in the organization should be available to answer trainee questions once they have begun working.

4 -- Test, certify and retrain

Your training should assure material retention and emphasize the importance of the effort. If properly implemented, testing and certification motivates and builds employee pride. Retraining or refresher training is an ongoing process that reinforces, reminds, and provides opportunities for implementing new or improved procedures. Establish a system to highlight when employees are due for retraining, retesting, or recertification

5 -- Feedback, auditing, and measurement

Motivate and provide the mechanism for program improvement. Sharing yield or productivity data with employees demonstrates the effectiveness of the program and of their efforts. Tracking these same numbers can indicate that it's time for retraining or whether modifications are required in the training program.

Design and delivery of an effective ESD training program can be just as important as the procedures and materials used in your ESD control program. A training program that is built on identifiable and measurable performance goals helps assure employee understanding, implementation and success.

Auditing

Developing and implementing an ESD control program itself is obvious. What might not be so obvious is the need to continually review, audit, analyze, feedback and improve. You will be asked to continually identify the program's return on investment and to justify the savings realized. Technological changes will dictate improvements and modifications. Feedback to employees and top management is essential. Management commitment will need reinforcement.

Like training, regular auditing becomes a key factor in the successful management of ESD control programs. The mere presence of the auditing process spurs compliance with program procedures. It helps strengthen management's commitment. Audit reports trigger corrective action and help foster continuous improvement.

The benefits to be gained from regular auditing of our ESD control procedures are numerous.

- They allow us to prevent problems before they occur rather than always fighting fires.
- They allow us to readily identify problems and take corrective action.
- They identify areas in which our programs may be weak and provide us with information

required for continuous improvement.

- They allow us to leverage limited resources effectively.
- They help us determine when our employees need to be retrained.
- They help us improve yields, productivity, and capacity.
- They help us bind our ESD program together into a successful effort.

An ESD audit measures performance to the defined standards and procedures of the ESD control program. Typically, we think of an ESD audit as a periodic review and inspection of the ESD work area covering use of the correct packaging materials, wearing of wrist straps, following defined procedures, and similar items. Auditing can range from informal surveys of the processes and facilities to the more formal third-party audits for ISO 9000 or ANSI/ESD S20.20 certification.

Requirements for Effective Auditing

Regardless of the structure, effective ESD auditing revolves around several factors. First, auditing implies the existence of written and well-defined standards and procedures. It is difficult to measure performance if you do not have anything to measure against. Yet, you quite frequently hear an auditor ask, "Some people say you should measure less than 500 volts in an ESD protected area, but others say you should measure less than 100 volts. What's acceptable when I audit the factory floor?" Obviously, this question indicates a lack of standards and the audit will be relatively ineffective.

Second, most audits require the taking of some measurements -- typically resistance and the presence of charge or fields. Therefore, you will need specific instrumentation to conduct work area audits. As a minimum, you will need an electrostatic field meter, a wide range resistance meter, a ground/circuit tester, and appropriate electrodes and accessories. Although this equipment must be accurate, it need not be as sophisticated as laboratory instruments. The audit is intended to verify basic functions and not as a full qualification of ESD control equipment or materials. You want the right tool for the job. Remember, many of the instruments you might choose for auditing are good indicators, but not suitable for precise evaluation of materials. Be sure that you can correlate the values obtained with those obtained in the laboratory.

Third, our audits need to include all areas in which ESD control is required to protect electrostatic discharge sensitive devices. Typically these areas would include receiving, inspection, stores and warehouses, assembly, test and inspection, research and development, packaging, field service repair, offices and laboratories, and clean rooms. Similarly, we need to audit all of the various processes, materials, and procedures that are used in our ESD control programs -- personnel, equipment, wrist straps, floors, clothing, worksurfaces, training, and grounding.

Fourth, we need to audit frequently and regularly. The actual frequency of audits depends upon your facility and the ESD problems that you have. Following initial audit, some experts recommend auditing each department once a month if possible and probably a minimum of six times per year. If this seems like a high frequency level, remember that these regular audits are based upon a sampling of work areas in each department, not necessarily every workstation. Once you have gotten your program underway, your frequency of audit will be based on your experience. If your audits regularly show acceptable levels of conformance and performance, you can reduce the frequency of auditing. If, on the other hand, your audits regularly uncover continuing problems, you may need to increase the frequency.

Fifth, we need to maintain trend charts and detailed records and prepare reports. They help assure that specified procedures are followed on a regular basis. The records are essential for quality control purposes, corrective action and compliance with ISO-9000.

Finally, upon completion of the audit, it is essential to implement corrective action if deficiencies are discovered. Trends need to be tracked and analyzed to help establish corrective action, which may include retraining of personnel, revision of requirement documents or processes, or modification of the existing facility.

Types of Audits

There are several types of ESD audits: program management audits, quality process checking, and work place audits. Each type is distinctively different and each is vitally important to the success of the ESD program

Program management audits measure how well a program is managed and how strong management commitment is. The program management audit emphasizes factors such as the existence of an effective implementation plan, realistic program requirements, ESD training programs, regular audits, and other critical factors of program management. The program management audit typically is conducted by a survey specifically tailored to the factors being reviewed. Because it's a survey, the audit can be conducted without actually visiting the site. The results of this audit indirectly measure work place compliance and are particularly effective as a means of self-assessment for small companies as well as large global corporations.

Quality process checking applies classical statistical quality control procedures to the ESD process and is performed by operations personnel. This is not a periodic audit, but rather daily maintenance of the program. Visual and electrical checks of the procedures and materials, wrist strap testing for example, are used to monitor the quality of the ESD control process. Checking is done on a daily, weekly or monthly basis.

Trend charts and detailed records trigger process adjustments and corrective action. They help assure that specified procedures are followed on a regular basis. The records are essential for quality control purposes, corrective action and compliance with ISO-9000.

Work place audits verify that program procedures are followed and that ESD control materials and equipment are within specification or are functioning properly. Audits are performed on a regular basis, often monthly, and utilize sampling techniques and statistical analysis of the results. The use of detailed checklists and a single auditor assures that all items are covered and that the audits are performed consistently over time.

Basic Auditing Instrumentation

Special instrumentation will be required to conduct work area audits. The specific instrumentation will depend on what you are trying to measure, the precision you require and the sophistication of your static control and material evaluation program. However, as a minimum, you will need an electrostatic field meter, a wide range resistance meter, a ground/circuit tester, and appropriate electrodes and accessories. Additional instrumentation might include a charge plate monitor, footwear and wrist strap testers, chart recorders and timing devices, discharge simulators, and ESD event detectors.

Although this equipment must be accurate, it need not be as sophisticated as laboratory instruments. The audit is intended to verify basic functions and not as a full qualification of ESD control equipment or materials. Remember, you want the right tool for job. Just as you would not buy a hammer if you are were planning to saw wood, you would not purchase an electrometer to measure static voltages on a production line. If you are making measurements according to specific standards, be sure the instrumentation meets the specifications of these standards.

With a hand held electrostatic field meter, you can measure the presence of electrostatic charge in your environment allowing you to identify problem areas and monitor your ESD control program. These instruments measure the electrostatic field associated with a charged object. Many field meters simply measure the gross level of the electrostatic field and should be used as general indicators of the presence of a charge and the approximate level of this charge. Others will provide more precise measurement for material evaluation and comparison.

For greater precision in facility measurements or for laboratory evaluation, a charge plate monitor can be attached to some field meters or connected to a voltmeter in the laboratory. With these additional tools you can evaluate the performance of flooring materials or balance ionizing equipment, for example.

Because resistance is one of the key factors in evaluating ESD control materials, a wide range resistance meter becomes a crucial instrument. Most resistance measurements are made at 100 volts, and some at 10 volts. The equipment you choose should be capable of applying these voltages to the materials being tested. In addition, the meter should be capable of measuring resistance ranges of 105 to 1011 ohms. With the proper electrodes and cables, you will be able to measure the resistance of flooring materials, worksurfaces, equipment, furniture, garments, and some packaging materials.

The final instrument is a ground/circuit tester. With this device you can measure the continuity of your ESD grounds and also check the impedance as well as neutral to ground shorts.

Areas, Processes, and Materials to be Audited

In our last column we stated that ESD protection was required "wherever ESDS devices are handled." Obviously, our audits need to include these same areas. Table 1 indicates some of the physical areas that require ESD protection and auditing of the program.

Table 1
Typical Facility Areas To Be Audited

Receiving
Inspection
Stores and Warehouses
Assembly
Test and Inspection
Research and Development
Packaging
Field Service Repair
Offices and Laboratories
Clean Rooms

Similarly, we need to conduct work area and program management audits all of the various processes, materials, and procedures that are used in our ESD control programs. Some of these are shown in Table 2.

Table 2 Typical Processes, Materials and Procedures To Be Audited
Personnel
Moving Equipment (Carts, lift trucks)
Wrist Straps
Floors, Floor Mats, Floor Finishes
Shoes, Grounders, Casters
Clothing

Workstations
Worksurfaces
Packaging and Materials Handling
Ionization
Grounding
Production Equipment
Tools and Equipment (Soldering irons, fixtures, etc.)
Labeling and Identification
Purchasing Specifications and Requisitions
ESD Control Program Procedures and Specifications
ESD Measurement and Test Equipment
Personnel Training
Engineering Specifications and Drawings

Check Lists

Check lists can be helpful tools for conducting work place and program audits. However, it is important that ESD control program requirements are well documented and accessible to avoid a tendency for checklists becoming de facto lists of requirements. Table 3 indicates the type of questions and information that might be included in an auditing check list. Your own check lists, of course, will be based on your specific needs and program requirements. They should conform to your actual ESD control procedures and specifications and they should be consistent with any ISO 9000 requirements you may have.

In addition to check lists, you will use various forms for recording the measurements you make: resistance, voltage generation, etc. Part of your audit will also include the daily logs used on the factory floor such as those used for wrist strap checking.

Table 3 Sample Audit Check List ESD Control Program			
Function/Area Audited: Personnel Date: Auditor:			
Audit Questions	**Y**	**N**	**Comments**
1. Where ESD protective flooring is used for personnel grounding, are foot grounding devices or conductive footwear worn?			
2. Where conductive floors and footwear are used for personnel grounding, do personnel check continuity to ground upon entering the area?			
3. Are personnel wearing grounded wrist straps at the ESD protective workstations?			
4. Are personnel checking wrist straps for continuity or using a continuous ground monitor?			
5. Where continuous ground monitors are not used, are wrist straps checked and logged routinely and at frequent intervals?			
6. Are wriststrap checkers and continuous ground monitors checked and maintained periodically?			
7. Do wrist straps and foot grounders fit correctly?			
8. Are wrist straps and foot grounders working correctly?			

9. Are wrist strap cords checked, on the person, at the workstation?			
10. Are disposable foot grounders limited to one time use?			
11. Are test records for wrist straps and foot grounders kept and maintained?			
12. When required, are ESD protective garments correctly worn?			
13. Are nonessential personal items kept out of ESD controlled areas?			
14. Are finger cots and gloves being used on ESD sensitive hardware made of ESD protective material, or treated to be ESD protective?			
15. Are personnel working in the ESD controlled area currently certified or escorted?			
16. Are all personnel with access to the ESD controlled area trained?			
17. Are ESD Control requirements imposed on visitors?			

Reporting and Corrective Action

Upon completion of the auditing process, Reports should be prepared and distributed in a timely manner. Details of the audits need to be fully documented for ISO-9000 or ANSI/ESD S20.20 certification. As with all audits, it is essential to implement corrective action if deficiencies are discovered. Trends need to be tracked and analyzed to help establish corrective action, which may include retraining of personnel, revision of requirement documents or processes, or modification of the existing facility.

Conclusion

Auditing and training are key elements in maintaining an effective ESD control program. They help assure that procedures are properly implemented and can provide a management tool to gauge program effectiveness and make continuous improvement.

Device Sensitivity and Testing

In Part Two of this series, we indicated that a key element in a successful static control program was the identification of those items (components, assemblies, and finished products) that are sensitive to ESD and the level of their sensitivity. Damage to an ESDS device by the ESD event is determined by the device's ability to dissipate the energy of the discharge or withstand the current levels involved. This is known as device "ESD sensitivity" or "ESD susceptibility".

Some devices may be more readily damaged by discharges occurring within automated equipment, while others may be more prone to damage from handling by personnel. In this article we will cover the models and test procedures used to characterize, determine, and classify the sensitivity of components to ESD. These test procedures are based on the three primary models of ESD events: Human Body Model (HBM), Machine Model (MM), and Charged Device Model (CDM). The models used to perform component testing cannot replicate the full spectrum of all possible ESD events. Nevertheless, these models have been proven to be successful in reproducing over 95% of all ESD field failure signatures. With the use of standardized test procedures, the industry can

- Develop and measure suitable on-chip protection.
- Enable comparisons to be made between devices.
- Provide a system of ESD sensitivity classification to assist in the ESD design and monitoring requirements of the manufacturing and assembly environments.
- Have documented test procedures to ensure reliable and repeatable results.

Human Body Model

One of the most common causes of electrostatic damage is the direct transfer of electrostatic charge through a significant series resistor from the human body or from a charged material to the electrostatic discharge sensitive (ESDS) device. When one walks across a floor, an electrostatic charge accumulates on the body. Simple contact of a finger to the leads of an ESDS device or assembly allows the body to discharge, possibly causing device damage. The model used to simulate this event is the Human Body Model (HBM).

The Human Body Model is the oldest and most commonly used model for classifying device sensitivity to ESD. The HBM testing model represents the discharge from the fingertip of a standing individual delivered to the device. It is modeled by a 100 pF capacitor discharged through a switching component and a 1.5kW series resistor into the component. This model, which dates from the nineteenth century, was developed for investigating explosions of gas mixtures in mines. It was adopted by the military in MIL-STD-883 Method 3015, and is also used in ESD Association standard ESD STM5.1: Electrostatic Discharge Sensitivity Testing -- Human Body Model. A typical Human Body Model circuit is presented in Figure 1.

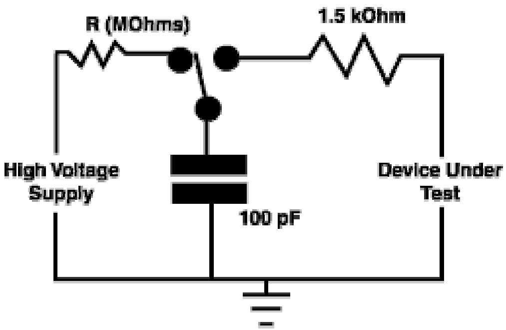


Figure 1: Typical Human Body Model Circuit

Testing for HBM sensitivity is typically performed using automated test systems. The device is placed in the test system and contacted through a relay matrix. ESD zaps are applied and the post stress I-V current traces are reviewed to see if the devices fail. The ESD Association HBM test standard was recently revised to include several technical changes. First, the number of zaps per stress level and polarity has been reduced from 3 to 1. Also, the minimum time interval between zaps has been reduced from 1 second to 300 milliseconds. The changes reduce the HBM qualification test time.

The second technical change is a revision in the HBM tester specifications. The maximum rise time for an HBM wave form measured through a 500 ohm load was relaxed from 20 to 25 nanoseconds. This will allow HBM test equipment manufacturers to build high pin count testers that typically have a higher parasitic test board capacitance that slows down the 500 ohm wave form.

Machine Model

A discharge similar to the HBM event also can occur from a charged conductive object, such as a metallic tool or fixture. Originating in Japan as the result of trying to create a worst-case HBM event, the model is known as the Machine Model. This ESD model consists of a 200 pF capacitor discharged directly into a component with no series resistor.

As a worst-case human body model, the Machine Model may be over severe. However, there are real-world situations that this model represents, for example the rapid discharge from a charged board assembly or from the charged cables of an automatic tester.

Testing of devices for MM sensitivity using ESD Association standard *ESD STM5.2: Electrostatic Discharge Sensitivity Testing* -- *Machine Model* is similar to HBM testing. The test equipment is the same, but the test head is slightly different. The MM version does not have a 1,500 ohm resistor, but otherwise the test board and the socket are the same as for HBM testing. The series inductance, as shown in Figure 2, is the dominating parasitic element that shapes the oscillating machine model wave form. The series inductance is indirectly defined through the specification of various waveform parameters.

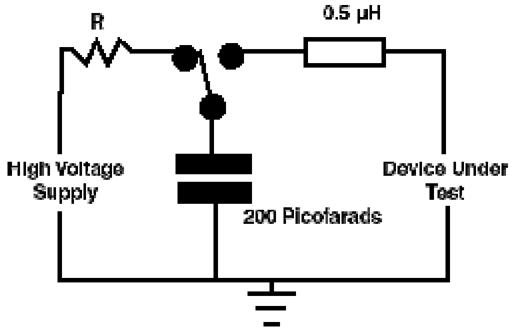


Figure 2: Typical Machine Model Circuit

Charged Device Model

The transfer of charge from an ESDS device is also an ESD event. A device may become charged, for example, from sliding down the feeder in an automated assembler. If it then contacts the insertion head or another conductive surface, a rapid discharge may occur from the device to the metal object. This event is known as the Charged Device Model (CDM) event and can be more destructive than the HBM for some devices. Although the duration of the discharge is very short--often less than one nanosecond--the peak current can reach several tens of amperes.

Several test methods have been explored to duplicate the real-world CDM event and provide a suitable test method that duplicates the types of failure that have been observed in CDM caused field failures. Current work in the area is concentrating on two separate CDM test methods. One is termed CDM and best replicates the real world charged device event. The other addresses devices that are inserted in a socket and then charged and discharged in the socket. It is termed the socketed discharge model (SDM).

The device testing standard for CDM *(ESD STM5.3.1: Electrostatic Discharge Sensitivity Testing - Charged Device Model)* was published in 1999. The test procedure involves placing the device on a field plate with its leads pointing up, then charging it and discharging the device. Figure 3 illustrates a typical CDM test circuit.

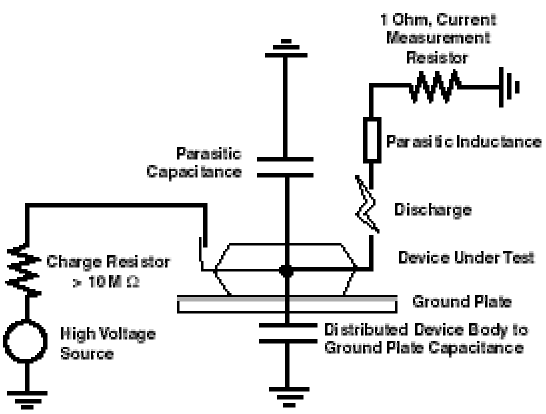


Figure 3: Typical Charged Device Model Test

SDM testing is similar to testing for HBM and MM sensitivity. The device is placed in a socket, charged from a high-voltage source and then discharged. This procedure is still a work in process and has had to overcome a number of limitations including too great a dependency on the specific design of the SDM tester. A draft document may be ready for release later this year or in 2002. A technical report, *ESD TR08-00: Socket Device Model (SDM) Tester* is also available from the ESD Association.

Device Sensitivity Classification

Each of the device testing methods includes a classification system for defining the component sensitivity to the specified model (See Tables 1, 2, and 3). These classification systems have a number of advantages. They allow easy grouping and comparing of components according to their ESD sensitivity and the classification gives you an indication of the level of ESD protection that is required for the component.

Table 1
ESDS Component Sensitivity Classification -Human Body Model
(Per ESD STM5.1-1998)

Class	Voltage Range
Class 0	<250 volts
Class 1A	250 volts to < 500 volts
Class 1B	500 volts to < 1,000 volts
Class 1C	1000 volts to < 2,000 volts
Class 2	2000 volts to < 4,000 volts
Class 3A	4000 volts to < 8000 volts
Class 3B	>=8000 volts

Table 2
ESDS Component Sensitivity Classification -Machine Model
(Per ESD-S5.2-1999)

Class	Voltage Range
Class M1	<100 volts
Class M2	100 volts to <200 volts
Class M3	200 volts to <400 volts
Class M4	> or = 400 volts

Table 3
ESDS Component Sensitivity Classification -Charged Device Model
(Per ESD-DS5.3-1999)

Class	Voltage Range

Class C1	<125 volts
Class C2	125 volts to < 250 volts
Class C3	250 volts to < 500 volts
Class C4	500 volts to < 1,000 volts
Class C5	1,000 volts to < 1,500 volts
Class C6	1,500 volts to <2,000 volts
Class C7	=>2,000 volts

A fully characterized component should be classified using all three models: Human Body Model, Machine Model, and Charged Device Model. For example, a fully characterized component may have the following: Class 1B (500 volts to <1000 volts HBM), Class M1 (<100 volts MM), and Class C3 (500 volts to <1000 volts CDM). This would alert a potential user of the component to the need for a controlled environment, whether assembly and manufacturing operations are performed by human beings or machines.

A word of caution, however. These classification systems and component sensitivity test results function as guides, not necessarily as absolutes. The events defined by the test data produce narrowly restrictive data that must be carefully considered and judiciously used. The three ESD models represent discrete points used in an attempt to characterize ESD vulnerability. The data points are informative and useful, but to arbitrarily extrapolate the data into a real world scenario can be misleading. The true utility of the data is in comparing one device with another and to provide a starting point for developing your ESD control programs.

Summary

Device failure models and device test methods define the sensitivity of the electronic devices and assemblies to be protected from the effects of ESD. With this key information, you can design more effective ESD control programs.

ESD Standards

The electronics industry is continually shifting. Device density and technology is more complex. Electronics manufacturing is more heavily reliant on out-sourcing. The ESD industry seems to have jumped into this swirling eddy headfirst. ESD control programs have mushroomed. Black has been replaced by green, blue and gold. Shielding bags dominate the warehouse. Ionizers exist along side wrist straps and ground cords. An early history of "smoke and mirrors," magic and lofty claims of performance is rapidly and safely being relegated to the past.

Today, more than ever, meeting the complex challenge of reducing ESD losses requires more than reliance on faith alone. Users require a way to legitimately evaluate and compare competing brands and types of products. They need objective confirmation that their ESD control program provides effective solutions to their unique ESD problems. Contract manufacturers and OEM's require mutually agreed-upon ESD control programs that reduce duplication of process controls.

That's where standards come into play. They provide guidance in developing programs that effective address ESD process control. They help define the sensitivity of the products manufactured and used. They help define the performance requirements for various ESD control materials, instruments, and tools. Standards are playing an ever-increasing role in reducing marketplace confusion in the manufacture, evaluation, and selection of ESD control products and programs.

The Who and Why of Standards

Who uses ESD standards? Manufacturers and users of ESD sensitive devices and products, manufacturers and distributors of ESD control products, certification registrars, and third party testers of ESD control products.

Why use ESD standards? They help assure consistency of ESD sensitive products and consistency of ESD control products and services. They provide a means of objective evaluation and comparison among competitive ESD control products. They help reduce conflicts between users and suppliers of ESD control products. They help in developing, implementing, auditing, and certifying ESD control programs. And, they help reduce confusion in the marketplace.

In the United States, the use of standards is voluntary, although their use can be written into contracts or purchasing agreements between buyer and seller. In most of the rest of the world, the use of standards, where they exist, is compulsory.

Key Standards and Organizations

Just 20 years ago, there were relatively few reliable ESD standards and few ESD standards development organizations. Today's ESD standards landscape is not only witnessing an increase in the number of standards, but also increasing cooperation among the organizations that develop them.

Today's standards fall into three main groups. First, there are those that provide ESD program guidance or requirements. These include documents such as *ANSI ESD S20.20-1999--Standard for the Development of an ESD Control Program, ANSI/ESD S8.1-ESD Awareness Symbols*, or *ESD TR20.20-ESD Handbook.*

A second group covers requirements for specific products or procedures such as packaging or grounding. Typical standards in this group are ANSI/ESD S6.1-Grounding or ESD S11.11 for Shielding Bags.

A third group of documents covers the standardized test methods used to evaluate products and materials. Historically, the electronics industry relied heavily on test methods established for other industries or even other materials (e. g., *ASTM-257-DC Resistance or Conductance of Insulating Materials*). Today, however, specific test method standards focus on ESD in the electronics environment, largely as a result of the ESD Association's activity. These include standards such as *ESD*

S5.1-Device Testing, Human Body Model and *ANSI/ESD S7.1: Floor Materials -- Resistive Characterization* to cite just a few.

Who Develops Standards?

Standards development and usage is a cooperative effort among all organizations and individuals affected by standards. There are several key ESD standards development organizations.

Military Standards

Traditionally, the U.S. military spearheaded the development of specific standards and specifications with regard to ESD control in the U.S. Today, however, U.S. military agencies are taking a less proactive approach, relying on commercially developed standards rather than developing standards themselves. For example, the ESD Association completed the assignment from the Department of Defense to convert MIL-STD-1686 into a commercial standard.

ESD Association

The ESD Association has been a focal point for the development of ESD standards in recent years. An ANSI-accredited standards development organization, the Association is charged with the development of ESD standards and test methods. The Association also represents the US on the International Electrotechnical Commission Technical Committee 101-Electrostatics.

The ESD Association has published 26 standards documents and 9 technical reports. These voluntary standards cover the areas of material requirements, electrostatic sensitivity, and test methodology for evaluating ESD control materials and products. In addition to standards documents, the Association also publishes a number of informational advisories.

ESD Association Standards Classifications and Definitions

There are four types of ESD Association standards documents with specific clarity of definition. The four document categories are consistent with other standards development organizations. These four categories are defined below.

Standard: A precise statement of a set of requirements to be satisfied by a material, product, system or process that also specifies the procedures for determining whether each of the requirements is satisfied.

Standard Test Method: A definitive procedure for the identification, measurement and evaluation of one or more qualities, characteristics or properties of a material, product, system or process that yields a reproducible test result.

Standard Practice: A procedure for performing one or more operations or functions that may or may not yield a test result. Note: If a test result is obtained, it may not be reproducible between labs.

Technical Report: A collection of technical data or test results published as an informational reference on a specific material, product, system, or process.

As new documents are approved and issued, they will be designated into one of these four new categories. Existing documents are being reviewed and will be reclassified as appropriate.

International Standards

The international community, led by the European-based International Electrotechnical Commission, has also climbed on board the standards express. Europe's CENELEC has issued a European electrostatic standard EN100015 - Protection of Electrostatic Sensitive Devices that was adopted as a European Norm. Additional work by the IEC to will result in a comprehensive series of standards that may someday be the successor to EN100015.

Japan also has released its proposed version of a national electrostatic Standard, which also shares many aspects of the European and U.S. documents.

Organizational Cooperation

Perhaps one of the more intriguing changes in ESD standards has been the organizational cooperation developing between various groups. One cooperative effort was between the ESD Association and the U.S. Department of Defense, which resulted in the Association preparing ANSI/ESD S20.20 as a successor to MIL-STD-1686.

Internationally, European standards development organizations and the ESD Association have developed working relationships that result in an expanded review of proposed documents, greater input, and closer harmonization of standards that impact the international electronics community.

For users of ESD standards, this increased cooperation will have a significant impact. First, we should see standards that are technically improved due to broader input. Second, we should see fewer conflicts between different standards. Finally, we should see less duplication of effort.

Summary

For the electronics community, the rapid propagation of ESD standards and continuing change in the standards environment mean greater availability of the technical references that will help improve ESD control programs. There will be recommendations to help set up effective programs. There will be test methods and specifications to help users of ESD control materials evaluate and select products that are applicable to their specific needs. And there will be guidelines for vendors of ESD products and materials to help them develop products that meet the real needs of their customers.

Standards will continue to fuel change in the international ESD community.

Principle ESD Standards

U.S. Military/Department of Defense

MIL-STD-1686C: Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

This military standard establishes requirements for ESD Control Programs. It applies to U.S. military agencies, contractors, subcontractors, suppliers and vendors. It requires the establishment, implementation and documentation of ESD control programs for static sensitive devices, but does NOT mandate or preclude the use of any specific ESD control materials, products, or procedures. It is being updated and converted to a commercial standard by the ESD Association. Although DOD has accepted the new ANSI/ESD S20.20 document as a successor, it has not yet taken action to cancel STD-1686

MIL-HBDK-263B: Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

This document provides guidance, but NOT mandatory requirements, for the establishment and implementation of an electrostatic discharge control program in accordance with the requirements of MIL-STD-1686.

MIL-PRF 87893-Workstation, Electrostatic Discharge (ESD) Control

This document defines the requirements for ESD protective workstations.

MIL-B-81705-Barrier Materials, Flexible, Electrostatic Protective, Heat Sealable

This documents defines requirements for ESD protective flexible packaging materials.

MIL-STD-129-Marking for Shipment and Storage

Covers procedures for marketing and labeling ESD sensitive items.

International/European

EN100015: Protection of Electrostatic Sensitive Devices

Adopted in 1992 and 1993, this European Norm covers ESD handling practices for electronic devices.

ESD Association

Standards Documents

ESD S1.1-1998: Evaluation, Acceptance, and Functional Testing of Wrist Straps

A successor to EOS/ESD S1.0, this document establishes test methods for evaluating the electrical and mechanical characteristics of wrist straps. It includes improved test methods and performance limits for evaluation, acceptance, and functional testing of wrist straps.

ESD STM2.1-1997: Resistance Test Method for Electrostatic Discharge Protective Garments

This Standard Test Method provides test methods for measuring the electrical resistance of garments used to control electrostatic discharge. It covers procedures for measuring sleeve-to-sleeve and point-to-point resistance.

ESD STM3.1-2000: Ionization

Test methods and procedures for evaluating and selecting air ionization equipment and systems are covered in this standard. The document establishes measurement techniques to determine ion balance and charge neutralization time for ionizers.

ESD SP3.3-2000: Periodic Verification of Air Ionizers.

This Standard Practice provides test methods and procedures for periodic verification of the performance of air ionization equipment and systems (ionizers).

ESD S4.1- 1997(Revised): Worksurfaces - Resistance Measurements

This Standard establishes test methods for measuring the electrical resistance of worksurface materials used at workstations for protection of ESD susceptible items. It includes methods for evaluating and selecting materials, and testing new worksurface installations and previously installed worksurfaces.

ESD STM4.2-1998: Worksurfaces - Charge Dissipation Characteristics

This Standard Test Method provides a test method to measure the electrostatic charge dissipation characteristics of worksurfaces used for ESD control. The procedure is designed for use in a laboratory environment for qualification, evaluation or acceptance of worksurfaces.

ESD STM5.1-1998 Revised: Electrostatic Discharge Sensitivity Testing -- Human Body Model

This Standard Test Method updates and revises an existing Standard. It establishes a procedure for testing, evaluating and classifying the ESD sensitivity of components to the defined Human Body Model (HBM).

ESD STM5.2-1999 (Revised): Electrostatic Discharge Sensitivity Testing -- Machine Model

This Standard establishes a test procedure for evaluating the ESD sensitivity of components to a defined Machine Model (MM). It also provides a system of classifying the sensitivity of these components. The component damage caused by the Machine Model is often similar to that caused by the Human Body Model, but it occurs at a significantly lower voltage.

ESD STM5.3-1999: Electrostatic Discharge Sensitivity Testing - Charged Device Model -- Non-Socketed Mode

This Standard Test Method establishes a test method for evaluating the ESD sensitivity of active and passive components to a defined Charged Device Model (CDM).

ESD S6.1-1999: Grounding -- Recommended Practice

This Standard recommends the parameters, procedures, and types of materials needed to establish an ESD grounding system for the protection of electronic hardware from ESD damage. This system is used for personnel grounding devices, worksurfaces, chairs, carts, floors, and other related equipment.

ANSI ESD S7.1-1994: Floor Materials -- Resistive Characterization of Materials

Measurement of the electrical resistance of various floor materials such as floor coverings, mats, and floor finishes is covered in this document. It provides test methods for qualifying floor materials before installation or application and for evaluating and monitoring materials after installation or application.

ANSI ESD S8.1-1993: ESD Awareness Symbols

Three types of ESD awareness symbols are established by this document. The first one is to be used on a device or assembly to indicate that it is susceptible to electrostatic charge. The second is to be used on items and materials intended to provide electrostatic protection. The third symbol indicates the common point ground

ESD S9.1-1995: Resistive Characterization of Footwear

This Standard defines a test method for measuring the electrical resistance of shoes used for ESD control in the electronics environment.

ESD SP10.1-2000: Automated Handling Equipment

This Standard Practice provides procedures for evaluating the electrostatic environment associated with automated handling equipment.

ANSI ESD S11.11-1993: Surface Resistance Measurement of Static Dissipative Planar Materials

This Standard defines a direct current test method for measuring electrical resistance. The Standard is designed specifically for static dissipative planar materials used in packaging of ESD sensitive devices and components.

ESD STM11.12-2000: Volume Resistance Measurement of Static Dissipative Planar Materials

This Standard Test Method provides test methods for measuring the volume resistance of static dissipative planar materials used in the packaging of ESD sensitive devices and components.

ANSI ESD S11.31-1994: Evaluating the Performance of Electrostatic Discharge Shielding Bags

This Standard provides a method for testing and determining the shielding capabilities of electrostatic shielding bags.

ESD STM12.1-1997: Seating-Resistive Characterization

This Standard provides test methods for measuring the electrical resistance of seating used to control ESD. The test methods can be used for qualification testing as well as for evaluating and monitoring seating after installation. It covers all types of seating, including chairs and stools.

ESD STM13.1-2000: Electrical Soldering/Desoldering Hand Tools

This Standard Test Method provides electric soldering/desoldering hand tool test methods for measuring the electrical leakage and tip to ground reference point resistance and provides parameters for EOS safe soldering operation.

ANSI ESD S20.20-1999: Standard for the Development of an ESD Control Program

This Standard provides administrative, technical requirements and guidance for establishing, implementing and maintaining an ESD Control Program.

ESD STM97.1-1999: Floor Materials and Footwear – Resistance in Combination with a Person.

This Standard Test Method provides for measuring the electrical resistance of floor materials, footwear and personnel together, as a system.

ESD STM97.2-1999 Floor Materials and Footwear Voltage Measurement in Combination with a Person

This Standard Test Method provides for measuring the electrostatic voltage on a person in combination with floor materials and footwear, as a system.

Advisory Documents

Advisory Documents and Technical Reports are not Standards, but provide general information for the industry or additional information to aid in better understanding of Association Standards.

ESD ADV1.0-1994: Glossary of Terms

Definitions and explanations of various terms used in Association Standards and documents are covered in this Advisory. It also includes other terms commonly used in the ESD industry.

ESD ADV3.2-1995: Selection and Acceptance of Air Ionizers

This Advisory document provides end users with guidelines for creating a performance specification for selecting air ionization systems. It reviews four types of air ionizers and discusses applications, test method references, and general design, performance and safety requirements.

ESD ADV11.2-1995: Triboelectric Charge Accumulation Testing

The complex phenomenon of triboelectric charging is discussed in this Advisory. It covers the theory and effects of tribocharging. It reviews procedures and problems associated with various test methods that are often used to evaluate triboelectrification characteristics. The test methods reviewed indicate gross levels of charge and polarity, but are not necessarily repeatable in real world situations.

ESD ADV53.1-1995: ESD Protective Workstations

This Advisory document defines the minimum requirements for a basic ESD protective workstation used in ESD sensitive areas. It provides a test method for evaluating and monitoring workstations. It defines workstations as having the following components: support structure, static dissipative worksurface, a means of grounding personnel, and any attached shelving or drawers.

ESD TR 20.20: ESD Handbook

New handbook provides detailed guidance for implementing an ESD control program in accordance with ANSI/ESD S20.20.

Sources of Standards

ESD Association, 7900 Turin Road, Building 3, Rome, NY 13440. Phone: 315-339-6937. Fax: 315-339-6793. Web Site: http://www.esda.org

HIS Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112. Phone: 800-854-7179. Fax: 303-397-2740. Web Site: http://global.ihs.com

International Electrotechnical Commission, 3, rue de Varembe, Case postale 131, 1211 Geneva 20, Switzerland. Fax: 41-22-919-0300. Web Site: http://www.iec.ch/

Military Standards, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.