Fundamentals of Electrostatic Discharge

Part Two – Principles of ESD Control – ESD Control Program Development

In Part One of this series, Introduction to ESD, we discussed the basics of electrostatic charge and discharge, the mechanisms of creating charge, materials, types of ESD damage, ESD events, and ESD sensitivity. We concluded our discussion with the following summary:

1. Virtually all materials, including conductors, can be triboelectrically charged.
2. The amount of charge is affected by material type, speed of contact and separation, humidity, and several other factors.
3. Charged objects have electrostatic fields.
4. Electrostatic discharge can damage devices so a parameter fails immediately, or ESD damage may be a latent defect that may escape immediate detection, but may cause the device to fail prematurely.
5. Electrostatic discharge can occur throughout the manufacturing, test, shipping, handling, or operational processes, and during field service operations.
6. ESD 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 or susceptibility to ESD.

Protecting products from the effects of ESD damage begins by understanding these key concepts of electrostatic charges and discharges. An effective ESD control program requires an effective training program where all personnel involved understand the key concepts. Armed with this information, you can then begin to develop an effective ESD control program. In Part Two we will focus on some basic principles of ESD control and ESD control program development.

Basic Principles of Static Control

Controlling electrostatic discharge (ESD) in the electronics manufacturing environment is 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 static 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 Protection

The first principle is to *design products and assemblies to be as resistant 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. The Industry Council on ESD Target Levels and the ESD Association's "Electrostatic Discharge (ESD) Technology Roadmap", revised April 2010, suggest that designers will have less ability to provide the protection levels that were available in the past. Consequently, the ESD target levels are reduced to 1000 volts for Human Body Model robustness and 250 volts for robustness against the Charged Device Model, with tendency to reduce these values further. Those target values are considered to be realistic and safe levels for manufacturing and handling of today's products using basic ESD control methods as described in international industry standards as e.g. ANSI/ESD S20.20 or IEC 61340-5-1. When devices with lower ESD target levels must be used and handled, application-specific controls beyond the principles described here may be required.

2. Define the Level of Control Needed in Your Environment.

What is the most sensitive or ESD susceptible ESDS you are using and what is the classification of withstand voltage of the products that you are manufacturing and shipping? In order to get an idea of what is required, it is best to know the Human-Body Model (HBM) and Charged-Device Model (CDM) sensitivity levels for all devices that will be handled in the manufacturing environment. ANSI/ESD S20.20 and IEC 61350-5-1, both published in 2007, define control program requirements for items that are sensitive to 100 volts HBM; future version of those standards will most likely address also items that are sensitive to 200 volts CDM. With documentation, both standards allows requirements to be tailored as appropriate for specific situations.

3. Identify and Ddefine the Electrostatic Protected Areas (EPA).

Per Glossary ESD ADV1.0 an ESD protected area is "A defined location with the necessary materials, tools and equipment capable of controlling static electricity to a level that minimizes damage to ESD susceptible items". These are the areas in which you will be handling ESD sensitive items and the areas in which you will need to implement the basic ESD control procedures including bonding or electrically connecting all conductive and dissipative materials, including personnel, to a known common ground.

4. Reduce Electrostatic Charge Generation

If projections of ESD sensitivity are correct, ESD protection measures in product design will be increasingly less effective in minimizing ESD losses. The fourth principle of control is to *reduce electrostatic charge generation and accumulation* in the first place. It's fairly basic: no charge – no discharge. We begin by eliminating as many static charge generating processes or materials, specifically high-charging insulators such as common plastics, as possible from the

EPA work environment. We keep conductive/dissipative materials at the same electrostatic potential using equipotential bonding or attaching to equipment ground. Electrostatic discharge does not occur between materials kept at the same potential. In the EPA, ESD control items should be used in place of more common factory products such as worksurface mats, flooring, smocks, etc. which are to be attached to ground to reduce charge generation and accumulation. Personnel are grounded via wrist straps or a flooring/footwear system. While the basic principle of "controlling static electricity to a level that minimizes damage" should be followed, complete removal of charge generation is not achievable.

5. Dissipate and Neutralize

Because we simply can't eliminate all generation of electrostatic charge in the EPA, 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, personnel starting work may have a charge on their body; they can have that charge removed by attachment to a wrist strap or when they step on ESD flooring 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 magnitude of the discharge current can be controlled with static dissipative materials.

For some objects, such as common plastics and other insulators, being non-conductors grounding cannot remove an electrostatic charge because there is no pathway which is conductive enough to reduce the charge in a reasonable time. If the object cannot be eliminated from the EPA, ionization can be used to neutralize charges on these insulators. The ionization process generates negative and positive ions. The like charged ions are repelled from a charged object while the opposite charged ions are attracted to the surface of a charged object, therefore neutralizing the object (see Figure 1). If the ionizer is balanced, the net charge is zero.

6. Protect Products

Our final ESD control principle is to *prevent discharges that do occur from reaching susceptible parts and assemblies*. There are a variety of ESD control packaging and material handling products to use both inside and outside the EPA. One way is to protect ESD sensitive products and assemblies with proper grounding or shunting that will "dissipate" any discharge away from the product. A second method is to package, to store, or to transport ESD sensitive products in packaging that is low charging and are conductive/dissipative so can remove charges when grounded. In addition to these properties, packaging used to move ESD sensitive items outside the EPA should have the ESD control property of "discharge shielding". These materials should effectively shield the product from charges and discharges, 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, implementing, and maintaining an effective ESD control program (see Figure 2).

1. Establish an ESD Coordinator and ESD Teams

A team approach particularly applies to ESD because the problems and the solutions cross various functions, departments, divisions and suppliers in most companies. ESD team composition includes line employees as well as department heads or other management personnel. The ESD team may also cut across functions such as incoming inspection, quality, training, automation, packaging, and test. ESD teams or committees help assure a variety of viewpoints, the availability of the needed expertise, and commitment to success. An active ESD team helps unify the ongoing effort.

Heading this ESD team effort is an ESD program coordinator ("ESD 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 ESD coordinator also serves as the company's internal ESD consultant to all ESD control programs 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 product quality loss and ESD sensitivity data, you can evaluate your facility, looking for areas and procedures that may possibly cause ESD problems. Be on the lookout for things such as static generating materials, personnel handling procedures for ESD sensitive items, and contacts of ESD sensitive devices to conductors

Document your processes or work instructions. 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 proper resistance ranges and the presence of electrostatic fields in your environment.

Before seeking solutions to your problems, you will need to determine the extent of your product quality losses to ESD. These losses may be reflected in receiving reports, Quality Assurance and Quality Control 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. Where available, the potential for future problems as a result of technology roadmaps and internal product evolution should be considered.

Document your actual and potential ESD losses in terms of defective 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 the most sensitive to ESD noting the classification or withstand voltage. Note that two functionally identical items from two different suppliers may *not* have similar ESD ratings.

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 all departments have 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 or IEC 61340-5-1 and help you with ISO 9000 certification as well.

4. Build Justification to Get the Top Management Support

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. It may be useful to conduct a pilot program if the experience of other companies is not sufficient and you have an expectation that you can show meaningful results in the pilot.

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. Published articles such as *The "Real" Cost of ESD Damage* by Terry Welsher should be provided to top management.

5. Develop and Implement a Training Plan

Train and retrain your personnel in ESD control and your company's ESD control program and procedures. Training should include testing or other method to verify comprehension. 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. Please be aware that it might be necessary to tailor the ESD training to the education of the trainees.

ANSI/ESD S20.20 requires a written training plan, however, your company has the flexibility to determine how best to design the plan.

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, obtain 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. ESD 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. It is helpful to integrate the process improvement process into the overall quality system and use the existing quality tools such as root cause analysis and corrective action reports. As you find areas that need work, be sure to make the necessary adjustments to keep the program on track.

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.

ANSI/ESD S20.20 and IEC 61340-5-1 require a written compliance verification plan, however, your company has the flexibility to determine how best to design the plan. Test procedures are described in ESD TR53-01-06 Compliance Verification of ESD Protective Equipment and Materials which is available as complimentary download from www.ESDA.org. The objective is to identify if significant changes in ESD equipment and materials performance have occurred over time. Each user will need to develop their own set of test frequencies based on the critical nature of those ESD sensitive items handled and the risk of failure for the ESD protective equipment and materials.

Conclusion

Six principles of ESD control and six key elements to ESD control program development and implementation are your guideposts for effective ESD control programs.

The six basic principles of static control are:

1. Design in protection
2. Define the level of control needed in your environment
3. Identify and define the electrostatic protected areas (EPA)
4. Reduce electrostatic charge generation
5. Dissipate and neutralize
6. Protect products

Six key elements to to ESD control program development and implementation are:

1. Establish an ESD Coordinator and ESD teams
2. Assess your organization, facility, processes and losses
3. Establish and document your ESD control program plan
4. Build justification to get the top management support
5. Develop and implement a training plan
6. Develop and implement a compliance verification plan

In Part Three, we'll take a close look at specific procedures and materials that become part of your ESD control program.

For Additional Information

ANSI/ESD S20.20-2007 – Standard for the Development of Electrostatic Discharge Control Program, ESD Association, Rome, NY.

Dangelmayer, Theodore, *ESD Program Management: A Realistic Approach to Continuous, Measurable Improvement in Static Control*, 1999, Kluwer Academic Publishers, Boston, MA

ESD TR20.20, ESD Control Handbook, ESD Association, Rome, NY.

ESD TR53-01-06, Compliance Verification of ESD Protective Equipment and Materials, ESD Association, Rome, NY.

Industry Council on ESD Target Levels, White Paper I: "A Case for Lowering Component Level HBM/MM ESD Specifications and Requirements", Revision 2.0, October 2010.

Industry Council on ESD Target Levels, White Paper II: "A Case for Lowering Component Level CDM ESD Specifications and Requirements", Revision 2.0, April 2010.

ESDA Technology Roadmap, March 2013

IEC 61340-5-1, ed. 1.0, *"Electrostatics – Part 5.1: Protection of electronic devices from electrostatic phenomena – General requirements"*, IEC, Geneva, Switzerland, 2007-08.

Terry Welsher, *The "Real" Cost of ESD Damage*, InCompliance, May 01, 2010.

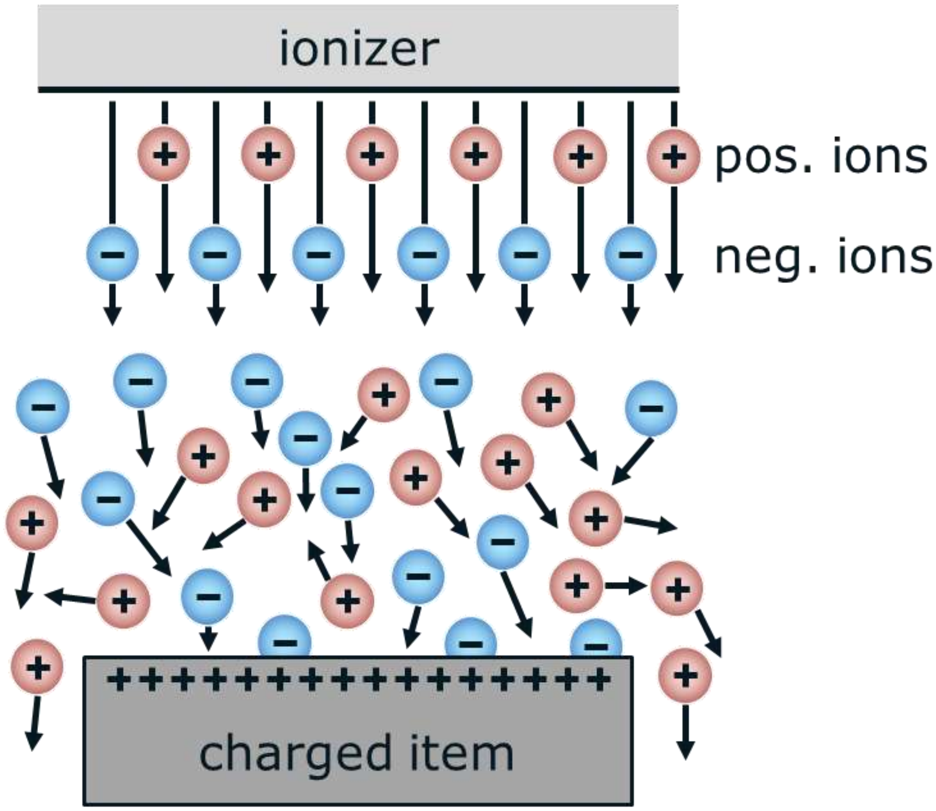

Figure 1: Prinziple of neutralization of a charged object by an ionizer that generates negative and positive ions. The like charged ions are repelled from a charged object while the opposite charged ions are attracted to the surface of a charged object, neutralizing the object

Figure 2: Six critical elements of a successful ESD control program