DVD-74C
ESD Control for Electronics Assembly

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ESD Overview

Electricity has often been used by brilliant scientists in their experiments. But left uncontrolled, the effects can be shocking!

ESD – the sudden transfer of electrostatic charge from one object to another. With lightning -- each flash is an immense discharge of static electricity – from a thundercloud where it has built up, into the earth below. Think about the crackling and sparks that occur when you remove clothes from a dryer. How about the shock you sometimes feel when you walk across a carpet and touch a doorknob? These examples of ESD -- which we can see and feel -- last for a fraction of a second and contain anywhere from about 2,000 volts – the lowest level most people can feel – to over 25,000 volts.

However, below 2,000 volts there is still enough static electricity to cause static discharge and damage electronic circuits even when we don't feel it. Still -- we're generating static electricity all the time. And a lot of common objects around us can be sources of static electricity too. In fact, static zaps under 20 volts are capable of damaging, or destroying the sensitive electronic components we handle every day. That transfer of static electricity – whether visible or not – is called electrostatic discharge, or ESD.

This video is about controlling static electricity to prevent ESD damage. You'll be introduced to ESD and see how it affects the world of electronics and electronics assembly. Then we'll take a look at how ESD can be controlled in a manufacturing facility – both in the work area and during the handling, storing and transporting of ESD sensitive devices.

So we can better understand what we're dealing with, let's examine the basic physics of static electricity, the primary cause of ESD. Electrostatic charge is created by contact and separation of materials. This phenomenon is known as *triboelectric charging*. It involves the transfer of electrons between materials. The resulting charge on a material may be positive, negative or neutral.

If one examines the smallest particle of a material, the atom, one sees that, protons are positive and reside inside the atom's nucleus. Electrons are negative and orbit at high speed around the outside of the nucleus. When any two materials are placed in direct contact and then are separated, negatively charged electrons are stripped from the surface of one material and transferred to the surface of the other material. Now, both materials are charged with static electricity.

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 because of the *absence* of negatively charged electrons, while the material that gains electrons is negatively charged due to the *abundance* of negatively charged electrons. An atom is neutral when there are an equal number of protons and electrons.

When there is an *imbalance* of electrons on the surface of a material an electrostatic charge exists, The symptom of a static charge is an *electrostatic field*. This field can be measured and can influence other objects in the near vicinity. Whenever two materials, such as nylon and polyester, are brought into contact with each other and are then *separated*, the two materials become charged. The charge is evident in that it may cause the hair on your arm to stand up.

When two corks are similarly charged, the corks will have the same polarity and repel each other. On the other hand, when one cork is charged negatively by the nylon and the other cork is charged positively by polyester, the corks will attract each other. In other words, we can see that like charges repel while opposite charges attract.

These charges are referred to as “static” or static electricity. The word static means “at rest” – so we can say the electrostatic charge is just sitting on the item – waiting for an opportunity to move, or discharge. Thus, ESD is the discharge of a charged object or material. When two conductive objects with different levels of charge come close together or in contact with one another, the charge rapidly moves from one object to the other. This rapid movement of the electrical charge changes it from static electricity to ESD.

It is important to understand how certain materials behave with these electrostatic charges. We’ll separate them into two categories – *conductors* and *insulators*. Conductors are typically some type of metal, like a piece of wire. The term conductor means that this material will conduct electricity. It will freely allow the movement of electrons across the surface or through it. This will enable us to use grounding techniques to eliminate charges. Grounding means providing a path for the charges to flow into the earth, leaving the material in an uncharged state.

There are other materials that are also conductors, but have a higher resistance to the flow of electricity – meaning they are not very good conductors. The human body and static dissipative materials are examples of these types of conductors. They will allow grounding techniques to be used, but electrical charges are drained slowly. This is actually a desired feature in many cases since draining charges slowly minimizes the chance of damaging electronic components.

The second material is called an insulator. Insulators prevent the flow of electricity. As with conductors, these materials can also become charged, but grounding techniques will have little to no effect on charge neutralization.

The last topic in this introductory section relates to the three failure models that were developed to characterize and determine the ESD sensitivity of a device. These are the Human Body Model, or HBM; the Machine Model, or MM; and the Charged Device Model, or CDM.

The Human Body Model refers to ESD damage to a component from the body of a charged person. The Machine Model refers to ESD damage to a component from a charged conductive object – such as a metallic tool or an ungrounded fixture. For Charged Device Model to occur, a charged device discharges to ground or to a conductor that has a different electrical potential. An example of the Charged Device

Model would be ESD damage to a component that gets charged sliding down a feeder in an automatic insertion machine, and then contacts an insertion head or another conductive surface.

People are a major potential source of ESD. That's because our bodies easily accumulate static electricity. In fact, our bodies can store relatively large amounts of this electrical charge. Door knobs probably don't mind the spark. But when ESD passes through an electronic device such as an integrated circuit, it can cause serious internal damage to that component – resulting in a scrapped component. The tiny circuit paths in these sensitive devices can be burned up, or severed by an ESD voltage so small that our sense of touch can't even detect it.

Remember, we can only feel discharges above about 2,000 volts, but some ESD sensitive components can be damaged by voltages less than 20 volts. And you won't even know the damage has occurred – but the destruction will exist inside the component. Even when the device is soldered onto a printed circuit board, it's still not safe. It can be damaged by a discharge that passes through the board's conductive traces to the ESD sensitive component.

The amount of voltage needed to damage or destroy varies from component to component, but as these devices become smaller and more complex, their sensitivity to ESD generally increases. Sometimes the damage caused by ESD doesn't mean the component will immediately fail. Instead, the assembly passes inspection, gets shipped to a customer – and then fails later on, creating a very unhappy customer.

ESD is one of the most serious problems facing the electronics industry today. If it isn't controlled, the results are higher costs, lower product quality and angry customers – especially if a product fails at a critical time. On the other hand, controlling ESD means product quality can be improved and costs can be kept down. This usually leads to increased customer satisfaction and sales – which is a win-win situation for everyone.

Personal Grounding for Seated Operations

Now that we know what ESD is, and what it can do to the electronic devices we handle, let's look at how ESD can be controlled in the work area. The most important thing we can learn about ESD control is that *we* are the most important part of ESD control. Although not every company has the same exact approach to ESD control, the major ESD standards state that ESD Protected Areas must have clearly identified boundaries and that training of personnel who handle ESD sensitive devices *is* required. This involves management putting up signs identifying ESD Protected Areas and making sure that ESD sensitive devices are properly labeled. In addition, engineering may control humidity; use air ionizers; and install static control flooring – and work surfaces. But none of these methods of ESD control really work without the complete participation and cooperation of every employee.

So – since *we* are one of the main culprits in the destruction of ESD sensitive devices, let's begin by taking a look at what equipment is available to reduce the risk of ESD damage from people. The idea is to drain off charges, in a controlled manner, before they reach the devices. To do that our bodies need to be connected to ground. If a charged ESD sensitive device comes into contact with a static dissipative surface, this contact safely channels the charge away from the ESD sensitive devices and drains them into the earth or ground.

There are several methods used to drain off charges that we might carry into an ESD safe area, or that we may generate while doing our jobs. The most common are the wrist strap and the shoe grounder. We'll take a look at the wrist strap first.

Wrist straps are very effective for any operation where people are seated at their workstations. They are also effective for standing operations that don't require much movement. Shoe grounders are not as effective when seated because people may raise their feet and lose contact with the static control flooring.

The wrist strap needs to be worn snugly against bare skin. It should be attached securely to a ground wire with a current limiting resistor – and some form of quick connect/disconnect. The current limiting resistor in the wrist strap cord limits the current flow through this intentional path to ground if the wearer comes into contact with sources of live power.

Wrist straps should be tested at regular intervals to make sure they are working properly. Your company will let you know where and how often you should do this. When testing the wrist strap, plug the cord into the wrist strap tester and press the test button. Shake your wrist and stretch the cord to check for intermittent failures. This test confirms continuity between the wrist cord, the wrist strap and the proper connection to your body. A *FAIL* indication means that one or more parts of the wrist strap system are faulty. If you experience any problem with your wrist strap, let your supervisor know immediately.

Personal Grounding for Standing Operations

Standing operations involve foot and floor ESD protective systems. We'll look at flooring first. Many facilities have ESD protected areas that contain static control flooring which includes grounded floor mats. These types of products minimize static charge generation and drain static electricity to ground from people wearing shoe grounders. Static control flooring may be conductive or static-dissipative. Some facilities do not have ESD protected areas with static control flooring installed. Shoe grounders will not work without static control flooring.

What exactly are shoe grounders and how do they work? Shoe grounders are designed to connect your body through your sock to static control flooring. There are basically two types of shoe grounders – sole grounders and heel straps. Sole grounders are the most effective of the two since they cover a large portion of the sole of the shoe. Heel straps only connect to the static control flooring from the heel of your shoe.

Shoe grounders are very effective for stand-up operations – especially if you need to move around a lot. This eliminates the problem of a long cord from the wrist strap. Most companies require the use of two shoe grounders for standing activities, and a wrist strap for seated operations.

The grounding strip should be placed between your sock and the inside of the shoe in such a way that you will be standing on the strip. There is enough moisture in your sock to provide a complete electrical connection from your body to ground. Visitors to ESD protected areas may be provided with disposable shoe grounders – which are worn once, then discarded. There are other ways of passing charges harmlessly to the ground. Static control footwear function like shoe grounders in that they provide a conductive path from your body through your sock and shoe to static control flooring.

When testing shoe grounders, place the foot with the strap on the metal plate and press the test button. The pass light indicates that the device is functioning properly. If wearing shoe grounders on both feet, test each foot individually. Testing both feet at the same time will not indicate a failure unless both straps fail. Static control footwear is tested the same way. As with shoe grounders, each foot should be tested individually. There are, however, some testers that have the capability of testing both feet at the same time.

Shoe grounders and static control footwear should be tested at regular intervals to make sure they're working properly. Again, your company will let you know where and how often you should do this. If you experience any problem with personal grounding devices, let your supervisor know immediately.

Continuous Monitoring

Now, let's discuss the use of continuous, or constant monitoring of wrist straps. The sad truth is that wrist straps typically don't fail just *before* you test them. In fact, they are more likely to fail *while* you are working with ESD sensitive devices.

The solution to this problem is the use of *continuous monitoring*. The continuous monitoring device contains an alarm that immediately notifies an operator when the wrist strap does not comply. Continuous monitors do not work for shoe grounders or static control footwear.

Static Control Smocks

Let's turn our attention to static control smocks. Static control smocks may be used to suppress *electrostatic fields* on an operator's clothing – and prevent those fields from causing field induced ESD damage. It's important to completely button the smock so no part of your clothing is exposed. Similarly, the sleeves should never be rolled up to the point where underlying clothing is exposed.

In some companies, static control smocks are not provided. Clothing made of cotton generates minimal charges because cotton is a neutral material. Clothing made from wool or polyester generates much larger charges. You should also avoid wearing loose clothing that drapes down and may come into contact with ESD sensitive devices.

Controlling Static Charges in Your Work Area

Now we'll take a closer look at an ESD Protected Area. Inside the boundaries of this area, you are responsible for following and enforcing company policies on ESD control. One way of controlling ESD in your work area is to eliminate any *non-essential* insulators, or non-conductive materials. Non-essential insulators are those items that are not required for the building of your products. These types of materials tend to generate and hold static charges – thereby creating electrostatic fields.

When a charged object such as these plastic safety glasses is brought close to an ESD sensitive device, the electric field causes charge separation in the ESD sensitive device. If the ESD sensitive device then comes in contact with a conductive item while exposed to the field, an ESD event occurs and the device can be damaged. Here are some examples of non-essential insulators that should be eliminated from your work area whenever possible.

Process required insulators are those items required to be used for your process – and therefore cannot be eliminated. There are, however, techniques that can help to deal with these charge-generating materials.

One technique is the use of an a*ir ionizer* to neutralize charges. The ionized air must be directed toward the charged item in order to neutralize any positive or negative charges that accumulate. Make sure that the air ionizer is turned on and that the airflow is directed where needed.

Another method of protecting ESD sensitive devices from process required insulators is to *arrange* the workstation so that static sensitive assemblies are no closer than 12 inches to the static generating materials – if that's possible. It may also be helpful to apply an anti-static solution to these hand tools at regular intervals. Again, the best ESD control solution is to eliminate all non-essential materials that generate and hold static charges.

In spite of all precautions, ESD sensitive devices will sometimes become charged. Therefore, it's important that they are not allowed to discharge rapidly – since the rapid transfer of a charge to a conductive surface may cause damage. A *static control material* is used to eliminate those harmful discharges –and may be found in various work surfaces and containers. These materials conduct electricity – but do it slowly enough to leave the ESD sensitive device undamaged.

The static dissipative work surface is most commonly used in this type of ESD control. If an ESD sensitive device becomes charged and is placed on this surface, the charge will flow between the device and the surface at a rate that will not harm the component.

On the other hand, this metal work surface is a good conductor of electricity – meaning that if the ESD sensitive device becomes charged and is placed on this surface, the electrostatic discharge will happen too quickly and may damage the device.

We've just looked at a number of ways to control ESD in our work area. ESD control works most effectively when you *assume* that all the components and assemblies that you handle are ESD sensitive – even when they're not. ESD sensitive devices should be properly labeled, but sometimes someone forgets. That's why it's important to get in the habit of performing all activities with ESD safe practices.

Another way to control ESD in the work area is to avoid activities that generate charges. These include combing hair or touching static generating materials. Remember, don't allow anyone into an ESD Protected Area unless they are trained and equipped per your company's procedures.

Handling, Packaging and Transporting ESD Sensitive Devices

Our last section deals with protecting ESD sensitive devices during handling – and when we transport them from one ESD protected area to another, or from one facility to another. We've already learned how to protect these devices from the static fields and uncontrolled discharges in the work area. Whether you're performing incoming inspection, storing items in the stockroom, kitting, doing assembly operations, or testing and troubleshooting, here are some tips for the safe handling of ESD sensitive devices.

Handle components, such as integrated circuits, by a non-conductive portion of the body rather than the leads. The leads are the most conductive pathway for an ESD event. The body of the component is less likely to provide a pathway for an ESD zap. Place the device with the leads down on a static dissipative surface. This way the component leads are all at the same electrical potential. And don't slide the device over any surface. Sliding can also generate static charges.

When handling electronic assemblies, it's important to hold them only by the edges – minimizing contact with any conductive surface. Because components are connected, an ESD charge to one component can easily spread to others. The key point for handling is to minimize handling of ESD sensitive items as much as possible.

Now let's turn our attention to ESD protective packaging. There are two categories of ESD protective packaging – *low charging and dissipative*; and *ESD shielding*, also known as *static shielding*. Low charging refers to a material's ability to resist triboelectric charge generation. This material does not generate or hold a charge, but it won't protect the enclosed product from a charge that comes from another source. Static shielding packaging actually protects the ESD sensitive device from static discharge. The charge will not be able to easily penetrate the packaging.

Low charging packaging is required for the movement of ESD sensitive items within an ESD protected area. It is considered optional to also use static shielding packaging. However, a combination of low charging *and* static shielding packaging is required when transporting ESD sensitive devices out of the ESD protected area to another job site – whether it is inside or outside of your facility.

Be aware that static shielding packaging doesn’t work unless it is closed and properly sealed. Carrying a circuit board assembly on top of ESD packaging, or using the ESD bag the way you’d use a potholder are not safe practices. That’s because the assembly is still exposed to ESD hazards. The point is that to achieve the full intended protection, bags or other types of packaging have to form a Faraday cage like enclosure – meaning the product must be fully enclosed – with absolutely no openings.

It’s also important to use clean containers that are the proper size for the device and are clearly marked for ESD sensitive items. And use only approved packaging materials.

When transporting ESD sensitive items, use push carts or racks that are designed for ESD sensitive devices. Again, your company will explain its policy regarding handling, storing and transporting ESD sensitive devices.

Summary

This program has presented the details of controlling ESD during electronics assembly. First, we discussed static electricity and took a look at how poor ESD practices can affect electronic components. Then we examined the ways of controlling ESD in our work area. This included wearing and testing our ESD personal grounding equipment; removing unnecessary materials; using static dissipative materials; and avoiding activities that cause ESD. We know that the best way to control static charges is to prevent their formation whenever possible.

We concluded with a discussion on the proper handling, storage and transport of ESD sensitive devices. ESD is everyone’s responsibility. You need to wear the appropriate equipment and to follow the proper procedures for handling, storing, and transporting ESD sensitive devices. And you need to report any problems or ESD hazards promptly. In this way, you can make the difference.