Toolbox Talks

Electrostatic Discharge (ESD) Awareness & Safety Part 1

STATIC ELECTRICITY, ELECTROSTATIC CHARGE

All materials can tribocharge or generate ElectroStatic charges. This is static electricity which is an electrical charge at rest. When an electrical charge is not at rest, but discharges, problems can occur & we will discuss ESD [ElectroStatic Discharge] in some detail later.

Remember that ElectroStatic charges & ElectroStatic discharges are different. All matter is constructed from atoms which have negatively charged electrons circling the atom's nucleus which includes positively charged protons. The atom having an equal number of electrons & protons balances out, having no charge.

ElectroStatic charges are most commonly created by contact & separation:

- When two surfaces contact then separate
- Some atom electrons move from one surface to the other, causing imbalance.

One surface has a positive charge & one surface has a negative charge.

CHARGE GENERATION OR TRIBOCHARGING EXA

The simple separation of two surfaces, as when tape is pulled off a roll, can cause the transfer of electrons between surfaces, generating an ElectroStatic charge.

- Unwinding a roll of tape
- Gas or liquid moving through a hose or pipe
- A person walking across a floor with heels & soles contacting & separating from the floor

The amount of static electricity generated varies & is affected by materials, friction, area of contact, & the relative humidity of the environment. At lower relative humidity, charge generation will increase as the environment is drier. Common plastics generally create the greatest static charges.

Typical Electrostatic Voltages

Many common activities may generate charges on a person's body that are potentially harmful to electronics components. (A higher charge is generated at low humidity, in a dry environment)

- Walking across carpet → 1,500 to 35,000 volts
- Walking over untreated vinyl floor → 250 to 12,500 volts
- Vinyl envelope used for work instructions → 600 to 7,000 volts
- Worker at bench → 700 to 6,000 volts
- Picking up a common plastic bag from a bench → 1,200 to 20,000 volts

ELECTROSTATIC DISCHARGE (ESD)

If two items are at the same electrostatic charge or equipotential, no discharge will occur. However if two items are at different levels of ElectroStatic charge, they will want to come into balance. If they are in close enough proximity, there can be a rapid, spontaneous transfer of electrostatic charge. This is called discharge or ElectroStatic Discharge (ESD).

Examples in daily life:

- Lightning, creating lots of heat & light

- The occasional zap felt when reaching for a door knob
- The occasional zap felt when sliding out of an automobile & touching the door handle

In a normal environment like your home, there are innumerable ESD events occurring, most of which you do not see or feel. It takes a discharge of about 2,000 volts for a person to feel the "zap". It requires a much larger ESD event to arc & be seen. **While a discharge may be a nuisance in the home, ESD is the hidden enemy in a high tech manufacturing environment.** Modern electronic circuitry can be literally burned or melted from these miniature lightning bolts. ESD control is necessary to reduce & limit these ESD events.

Even less than 100 volts might damage a component

TYPES OF ESD DEVICE DAMAGE

ESD damage to electronic components can be:

- Catastrophic Failures
- Latent Defects

Catastrophic failure causes a failure in an ESD sensitive item that is permanent. The ESD event may have caused a metal melt, junction breakdown, or oxide failure. Normal inspection is able to detect a catastrophic failure.

Direct catastrophic failures, meaning completely failed or dead components.

A **latent defect** can occur when an ESD sensitive item is exposed to an ESD event & is partially degraded. It may continue to perform its intended function, so it may not be detected by normal inspection. However, intermittent or permanent failures may occur at a later time.

Latent defects, meaning degradedor wounded components.

COSTLY EFFECTS OF ESD

A catastrophic failure of an electronic component can be the least costly type of ESD damage as it may be detected & repaired at an early manufacturing stage. Latent damage caused by ESD is potentially more costly since damage occurs that cannot be felt, seen, or detected through normal inspection procedures. Latent defects can be very expensive as the product passes all inspection steps, is completed, & shipped. Latent defects can severely impact the reputation of a company's product. Intermittent failures after shipping a product can be frustrating, particularly when the customer returns a product, reporting a problem which the factory again fails to detect. It consequently passes inspection & is returned to the customer with the problem unresolved.

The worst event is when the product is installed in a customer's system, & performs for a while & then performs erratically. It can be very expensive to troubleshoot & provide repairs in this situation.

Catastrophic failures are detected during inspection but components with latent defects pass as good.

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One UK study indicated the cost to be:
- £7 ($11.32) Device
- £7 ($11.32) Device in board - £700 ($1,132.13)
- £7 ($11.32) Device in board & in system - £7,000 ($11,321.30)
- £7 ($11.32) Device and system fails - £70,000 ($113,213)

Industry experts have estimated average electronics product losses due to static discharge to range from 8 to 33%. Others estimate the actual cost of ESD damage to the electronics industry as running into the billions of dollars annually.

ESD CONTROL

Many organizations consider all electronic components ESD sensitive. It is critical to be aware of the most sensitive item being handled in your workplace. As electronic technology advances, electronic circuitry gets progressively smaller. As the size of components is reduced, so is the microscopic spacing of insulators & circuits within them, increasing their sensitivity to ESD. As you can predict, the need for proper ESD protection increases every day. **Any ESD sensitive item should be identified with the ESD sensitivity symbol, either on itself or its container.**

The ESD Sensitivity Symbol (also called Susceptibility or Warning Symbol) identifies items that can be damaged by ESD & should be unpackaged & handled while grounded at an ESD protected workstation.
Most firms use the EN61340-5-1 standard to construct their ESD control plan which is based on handling ESD sensitive items having a Human Body Model withstand voltage of 100 volts or greater. The Human Body Model simulates discharges from a person & increasingly tests an electronic device at higher & higher discharges until it fails, thus establishing the device's withstand voltage.

OHM'S LAW

Ohm's law states that, in an electrical circuit, the current passing through a conductor between two points is directly proportional to the potential difference (i.e. voltage drop or voltage) across the two points, & inversely proportional to the resistance between them.
Resistance determines how much current will flow through a component. A very high resistance allows a small amount of current to flow. A very low resistance allows a large amount of current to flow. Resistance is measured in ohms.The measurement may be shown in various ways.

Most commonly:
- 1 kilohm
- 1 kW
- 1 x 10^3 ohm
- 1 x 10E3 ohm
- 10^3 ohm

Prefix	Symbol	Scientific Notation	Common Usage
kilo-	K	1 x 10^3 or 10E3	1,000 or one thousand
mega-	M	1 x 10^6 or 10E6	1,000,000 or one million
giga-	G	1 x 10^9 or 10E9	1,000,000,000 or one billion

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TYPES OF MATERIALS

Conductors
- Electrical current flows easily
- Can be grounded

When a conductor is charged, the ability to transfer electrons gives it the ability to be grounded.

Materials that easily transfer electrons (or charge) are called conductors & are said to have "free" electrons. Some examples of conductors are **metals**, **carbon**, & the **human body's sweat layer**. Grounding works effectively to remove ElectroStatic charges from conductors to ground. However, the item grounded must be conductive. The other term often used in ESD control is dissipative which is 1 x 10E4 to less than 1 x 10E11 ohms & is sufficiently conductive to remove ElectroStatic charges when grounded.

Insulators like this plastic* cup will *hold the charge & cannot be grounded & "conduct" the charge away.

Insulators
- Electrical current does not flow easily
- Cannot be grounded

Materials that do not easily transfer electrons are called insulators, by definition non-conductors. Some well known insulators are **common plastics**, & **glass**. An insulator will hold the charge & cannot be grounded & "conduct" the charge away. **Both conductors & insulators may become charged with static electricity & discharge.** Grounding is a very effective ESD control tool, however, only conductors (conductive or dissipative) can be grounded.

THINK OF STATIC ELECTRICITY AS GERMS AND CONTAMINATION

Damage caused by invisible & undetectable events can be understood by comparing ESD damage to medical contamination of the human body by viruses or bacteria. Although invisible, they can cause severe damage. In hospitals, the defense against this invisble threat is extensive contamination control procedures including sterilization.

Just as you would never consider having surgery in a contaminated operating room, you should never handle, assemble, or repair electronic assemblies without taking adequate protective measures against ESD.

We are aware of the benefits of sterilization in medicine. We must develop the same attitude towards ESD control & "sterilize" against its contamination.
For the hospital to sterilize most of the instruments is not acceptable; actually it may waste money. Each & every instrument needs to be sterilized. Likewise, it is not acceptable to protect the ESDS most of the time. Effective ESD control must occur at each & every step where ESDS are manufactured, processed, assembled, installed, packaged, labeled, serviced, tested, inspected, transported, or otherwise handled.

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OPERATOR'S PART IN ESD CONTROL

As an employee, the invisible threat of ESD should be of great concern to you. ESD damage can significantly reduce your company's profitability. This may affect your company's ability to compete in the marketplace, your profit sharing, and even your employment. Everyone likes to take pride in their work, but without proper ESD controls, your best efforts may be destroyed by ElectroStatic discharges that you can neither feel nor see.

People in the high-tech manufacturing environment are still a major source of ElectroStatic charges & discharges. Operators need training & to be vigilant that ESD control procedures are followed. In order for the ESD control program to be effective, operators must be aware of the threat of ESD & understand & adhere to the rules of controlling static electricity & how to properly use EPA ESD control items.

EPA ESD control items are ESD protective products that have been specially formulated to possess at least one of the ESD control properties:

1) low charging (antistatic)
2) resistance (conductive or dissipative, able to be grounded)
3) shielding

These products should be identified by the ESD Protective Symbol. **Note:** the ESD Protective Symbol has an arc which the ESD Susceptibility Symbol does not. The ESD Protective Symbol identifies products designed to provide ESD control protection.

FUNDAMENTAL ESD CONTROL PRINCIPLES

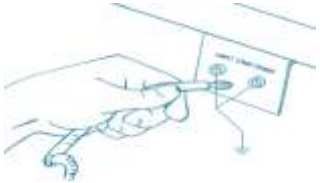
- Ground all conductors, including people
- Remove insulators, substitute with ESD protective versions, or neutralize with ionizers
- ESDS outside the EPA to be in packaging having ESD shielding property

PERSONNEL GROUNDING

A fundamental principle of ESD control is to ground conductors, including people, at ESD protected workstations. Wrist straps are the first line of defense against ESD, the most common personnel grounding device used, & are required to be used if the operator is sitting. The wristband should be worn snug to the skin with its coil cord connected to a common point ground which is connected to ground, preferably equipment ground.

If you are not using a continuous or a constant monitor, a wrist strap should be tested while being worn at least daily.

This quick check can determine that no break in the path-to-ground has occurred. Part of the path-to-ground is the perspiration layer on the person; an operator with dry skin may inhibit the removal of static charges & may cause a test failure. Specially formulated lotion can solve this problem.



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Failures may also be caused by dirty or loose wristbands, which should be cleaned or tightened. When a wrist strap fails a test, the supervisor should be contacted & the failure effectively addressed or the wrist strap replaced.

A Flooring / Footwear system is an alternative for personnel grounding for standing or mobile workers. Foot grounders or other types of ESD footwear are worn while standing or walking on an ESD floor. ESD footwear is to be worn on both feet & should be tested independently at least daily while being worn. Unless the tester has a split footplate, each foot should be tested independently, typically with the other foot raised in the air. Both ESD footwear & ESD floor are required. Wearing ESD footwear on a regular, insulative floor is a waste of time & money.

Part of the path-to-ground is the perspiration in the person's shoes. Foot grounder conductive tabs or ribbons should be placed inside the shoe under the foot with the excess length tucked into the shoe. Thanks to the perspiration in the shoe, direct contact with the skin is normally not necessary.

If an operator leaves the EPA & walks outside wearing ESD footwear, care should be taken not to get the ESD footwear soiled. Dirt is typically insulative, & the best practice is to re-test the ESD footwear while being worn each time when re-entering the EPA.

WORKSTATION GROUNDING DEVICES

ESD worksurfaces, such as mats, are typically an integral part of the ESD workstation, particularly in areas where hand assembly occurs. The purpose of the ESD worksurface is two-fold. (1) To provide a surface with little to no charge on it. (2) To provide a surface that will remove ElectroStatic charges from conductors (including ESDS devices & assemblies) that are placed on the surface.

ESD mats need to be grounded. A ground wire from the mat should connect to the common point ground which is connected to ground, preferably equipment ground. For electronics manufacturing, a worksurface resistance to ground (Rg) of 1 x 10E4 to less than 1 x 10E9 ohms is recommended. Best practice is that ground connections use firm fitting connecting devices such as metallic crimps, snaps, & banana plugs to connect to designated ground points. Use of alligator clips is not recommended. Operators should ensure that the worksurface is organized to perform work & that all unnecessary insulators & personal items are removed. Regular plastics, polystyrene foam drink cups & packaging materials, etc. are typically high charging & have no place at an ESD protective workstation. Insulators can be a considerable threat to your products. Remember that an insulator cannot be grounded, so it will retain its charge for a long time. Removing all non-essential insulators from the ESD protective workstation is an important rule. If not, the company's investment in the grounded ESD work surface may be wasted. If you do not believe so, please read the following paragraph.

The biggest threat is Field Induced Discharges, which can occur even at a properly grounded ESD worksurface. If an ESDS is grounded in the presence of an ElectroStatic charge, instead of the ESDS having charges removed from it, the ESDS may become charged with a voltage induced on it.

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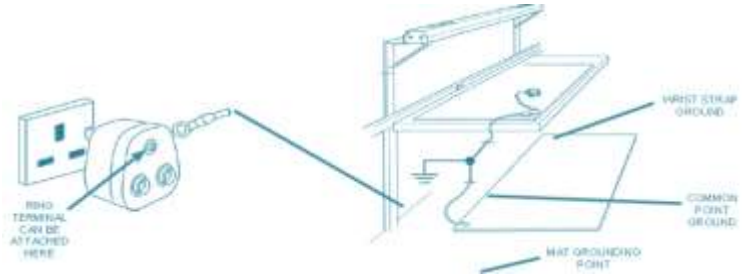
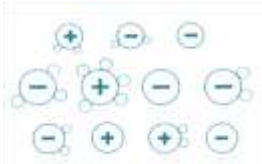
Then, when placed on the grounded ESD work surface, a discharge occurs. If the ESDS is removed from the presence of the ElectroStatic charge & grounded again, a second discharge may occur. (Ref. ESD Handbook, ESD TR20.20, section 2.7.5).The worksurface must be maintained & should be cleaned with an ESD cleaner. Regular cleaners typically contain silicone & should never be used on an ESD worksurface. The ESD control plan should require testing the resistance to ground periodically. However, the operator should be on guard every day & check visually that the ground wire is attached.



IONIZERS & NEUTRALIZATION

An ionizer creates great numbers of positively & negatively charged ions. Fans help the ions flow over the work area. Ionization can neutralize static charges on an insulator in a matter of seconds, thereby reducing their potential to cause ESD damage.

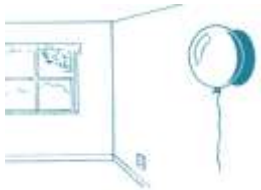


A fundamental principle of ESD control is to neutralize process essential insulators with ionizers. In addition, if a conductor is not grounded, it is an isolated conductor, & an ionizer is the only means to neutralize ElectroStatic charges on it. Insulators, by definition, are non-conductors & therefore cannot be grounded. **Besides neutralization using ionizers, insulators can be controlled by doing one of the following:**

- Keep insulators a minimum of 12" from ESDS items at all times
- Replace regular insulative items with an ESD protective version
- Periodically apply a coat of topical antistat

When none of the above is possible, the insulator is termed "process essential" & therefore neutralization using an ionizer should become a necessary part of the ESD control program.

Examples of some **common process essential insulators** are a PC board substrate, insulative test fixtures, & product plastic housings. An example of isolated conductors can be conductive traces or components loaded on a PC board that is not in contact with the ESD worksurface. Reduction of charges on insulators does occur naturally by a process called neutralization. Ions are charged particles that are normally present in the air, & as opposite charges attract, charges will be neutralized over time. A common example is a balloon rubbed against clothing & "stuck" on a wall by static charge.



The balloon will eventually drop. After a day or so, natural ions of the opposite charge that are in the air will be attracted to the balloon & will eventually neutralize the charge. An ionizer greatly speeds up this process. **Note:** Ionizers require periodic cleaning of emitter pins, & the offset voltage must be kept in balance. Otherwise, instead of neutralizing charges, if it is producing primarily positive or negative ions, the ionizer will place an electrostatic charge on items that are not grounded.

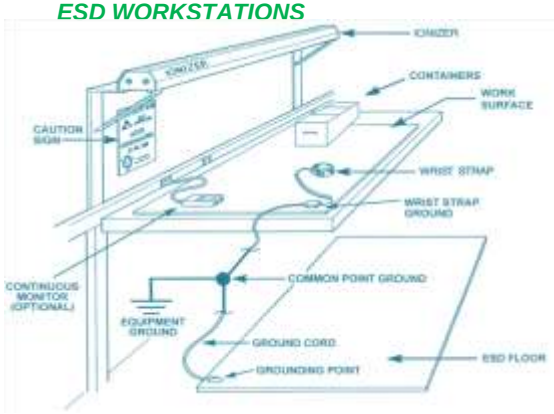
SHIELDING

The third fundamental principle of the ESD control system is to package ESD sensitive components & assemblies during storage or transportation outside the EPA enclosed in packaging that possesses the ESD control property of shielding. In shielding, we utilize the fact that electrostatic charges & discharges take the path of least resistance. The charge will be either positive or negative; otherwise the charge would balance out & be no charge. Like charges repel & so the electrostatic charge will reside on the outer surface. A Faraday Cage effect can protect ESDS contents in a shielding bag, or other container with a shielding layer. This Faraday Cage effect protects people in real life when a lightning bolt strikes an airplane or automobile with the charge residing on the outer metal fuselage or car body.To complete the enclosure,, make sure to place lids on boxes or containers, & close shielding bags. Packaging with holes, tears, or gaps should not be used as the contents may be able to extend outside the enclosure & lose their shielding as well as mechanical protection. When ESD sensitive items are unpackaged from shielding bags or other containers, they should be handled by a grounded operator at an ESD workstation.

The Faraday cage effect causes charges to be conducted around the outside of the surface of the conductor. Since like charges repel, charges will rest on the exterior.

Cover must be in place to create Faraday Cage & shield contents.

ESD WORKSTATIONS



ADDITIONAL EPA ESD CONTROL ITEMS:

- ESD smocks & gloves
- ESD packaging, bags, & boxes
- Conductive foam & shunt bars
- Antistatic or low charging tape
- ESD cleaners & topical antistat
- Dissipative bottles & cups
- Dissipative binders
- Dissipative document & badge holders
- Dissipative floor finishes
- Conductive paint & epoxy
- Conductive & dissipative flooring
- ESD hand lotion