DESCO EUROPE

ESD AWARENESS BOOKLET

PLEASE READ THOROUGHLY BEFORE WORKING ON OR HANDLING ESD SUSCEPTIBLE COMPONENTS OR ASSEMBLIES

Use as part of Training Plan required by EN 61340-5-1

ESD CONTROL PROGRAMME PLAN PER EN 61340-5-1

“The organization shall prepare an ESD control program plan that addresses each of the requirements of the program. Those requirements are:

- training,
- product qualification,
- compliance verification,
- grounding/bonding systems,
- personnel grounding,
- EPA requirements,
- packaging systems,
- marking.”

[EN 61340-5-1 Edition 2.0 – 2016-05 ESD control program plan clause 5.2.1]

“Each company has different processes, and so will require a different blend of ESD prevention measures for an optimum ESD control program. It is vital that these measures are selected, based on technical necessity and carefully documented in an ESD control program plan, so that all concerned can be sure of the program requirements.”
[EN 61340-5-1 Edition 2.0 – 2016-05 Introduction]

TRAINING PLAN

“The training plan shall define all personnel that are required to have ESD awareness and prevention training. At a minimum, initial and recurrent ESD awareness and prevention training shall be provided to all personnel who handle or otherwise come into contact with any ESDS. Initial training shall be provided before personnel handle ESD sensitive devices. The type and frequency of ESD training for personnel shall be defined in the training plan. The training plan shall include a requirement for maintaining employee training records and shall document where the records are stored. Training methods and the use of specific techniques are at the organization’s discretion. The training plan shall include methods used by the organization to ensure trainee comprehension and training adequacy.”
[EN 61340-5-1 Edition 2.0 – 2016-05 Training plan clause 5.2.2]

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“This part of IEC 61340 applies to activities that: manufacture, process, assemble, install, package, label, service, test, inspect, transport or otherwise handle electrical or electronic parts, assemblies and equipment with withstand voltages greater than or equal to 100 V HBM (Human Body Model), 200 V CDM (Charged Device Model) and 35 V for isolated conductors. ESDS (ESD Sensitive items) with lower withstand voltages may require additional control elements or adjusted limits.”
[EN 61340-5-1 Edition 2.0 – 2016-05 Scope clause 1]

ESD BASICS FOR ESD PROGRAMME PER EN 61340-5-1

ElectroStatic Discharge [ESD] can damage components and products containing electronics. It is the hidden enemy in many high-tech factories. Often this damage cannot be detected by quality control inspections, and can be very frustrating; adversely impacting productivity, quality, product reliability and thus a company's reputation and profitability.

The prerequisites of ESD control are:
- Identify ESD Protected Area [EPA]
- Identify ESD sensitive items [ESDS]
- Provide ESD control training.

The ESD protected area should have signage, often including aisle tape, to clearly identify where it is. You need to understand and follow the basics of ESD control to limit the generation of ElectroStatic charges, limit and slow discharges in the EPA.

ESD BASICS

Protect your work following these guidelines:
- Only handle unpackaged ESD sensitive items [ESDS] in the ESD protected area [EPA] when grounded
- Only allow trained or escorted people in the EPA
- Ground all conductors including people in the EPA
- Use continuous monitors or test wrist straps at least daily
- If ESD footwear is used, test at least daily
- Visually check that grounding cords are connected
- Keep wristband snug, foot grounder grounding tab in shoe, and ESD smocks covering all clothing on torso
- Keep work area clean and clear of all non-essential insulators, or neutralise essential insulators with ionisers with the airflow directed towards the work area
- Use packaging with shielding properties to store or transport ESDS outside the EPA.

GROUNDING AND PERSONNEL SAFETY

This booklet will deal with ESD basics. ElectroStatic charges or static electricity can be everywhere, however conductors can be effectively grounded and charges removed to ground. A fundamental rule in ESD control is to ground all conductors, including people.

However, while ESD control is important, it is of secondary importance to employee safety. Personnel should not be grounded in situations where they could come into contact with voltage over 250 volts AC.

"The procedures and equipment described in this standard may expose personnel to hazardous electrical conditions. Users of this standard are responsible for selecting equipment that complies with applicable laws, regulatory codes and both external and internal policy. Users are cautioned that this standard cannot replace or supersede any requirements for personnel safety. Electrical hazard reduction practices shall be exercised and proper grounding instructions for equipment shall be followed."
[EN 61340-5-1 Edition 2.0 – 2016-05 Personnel safety clause 4]

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 and we will discuss ESD [ElectroStatic Discharge] in some detail later.

Static electricity can be a very hair-raising event.

Remember that ElectroStatic charges and 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 and protons balances out having no charge.

ElectroStatic charges are most commonly created by contact and separation:

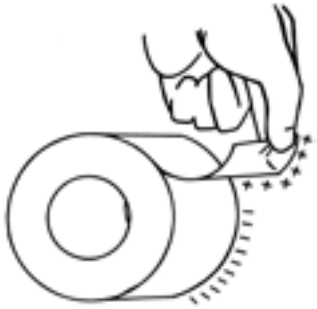
- When two surfaces contact then separate
- Some atom electrons move from one surface to the other, causing imbalance.

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

CHARGE GENERATION OR TRIBOCHARGING EXAMPLES

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 and soles contacting and separating from the floor.

The amount of static electricity generated varies, and is affected by materials, friction, area of contact, and the relative humidity of the

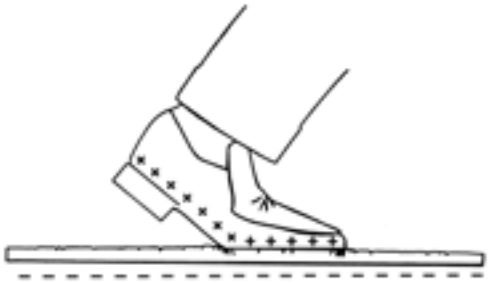
"For most people, static electricity is represented by the noise or crackle heard on a radio that interferes with good reception or the shock experienced when touching a metal object after walking across a carpeted room or sliding across a car seat. Static electricity is also observed as static cling when clothes are stuck together after coming out of a clothes dryer. Most of the time, people observe static electricity when the weather is cold and dry. While many people tend to think of static electricity as being at rest or not moving, static electricity causes the most concern when it ceases to be stationary."
[ESD Handbook ESD TR20.20 section 2.1 Basics of Static Electricity, Introduction]

"Any contact and physical separation of materials or flow of solids, liquids, or particle-laden gases can generate electrostatic charges. Common sources of ESD include charged: personnel, conductors, common polymeric materials, and processing equipment." [EN 61340-5-1 Edition 2.0 – 2016-05 Introduction]

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 electronic 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.

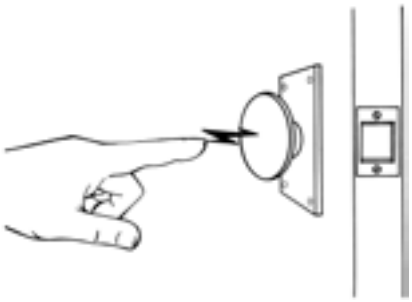
ELECTROSTATIC DISCHARGE (ESD)

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 and light

• The occasional zap felt when reaching for a doorknob



• The occasional zap felt when sliding out of an automobile and touching the door handle.

"ESD or electrostatic discharge, rapid transfer of charge between bodies that are at different electrostatic potentials."
[EN 61340-5-1 Edition 2.0 – 2016-05 Terms and definitions clause 3.5]

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 and 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 and limit these ESD events.

TYPES OF ESD DEVICE DAMAGE

ESD damage to electronic components can be:

- Catastrophic failures
- Latent defects.

EVEN LESS THAN 100 VOLTS MIGHT DAMAGE A COMPONENT

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 and is partially degraded. It may continue to perform its intended function, so may not be detected by normal inspection. However, intermittent or permanent failures may occur at a later time.

Latent defects, meaning degraded or wounded components.

COSTLY EFFECTS OF ESD

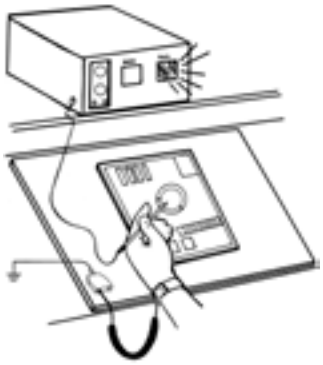
A catastrophic failure of an electronic component can be the least costly type of ESD damage as it may be detected and repaired at an early manufacturing stage.

“Failure mechanisms can include the following. Dielectric breakdown is a predominant failure mechanism on MOS devices when the voltage across the oxide excedes the dielectric breakdown strength. This failure mechanism is basically voltage dependent. The thinner the oxide, the higher the susceptibility to ESD. This failure mechanism can occur on MOS or bipolar devices, ... With bipolar devices, resistive leakage paths may occur where metallization runs over insulation which is above active semiconductor regions. Thermal breakdown occurs when the bonding materials melt, particularly in the case of eutectic alloy of silicon contact material, or of silicon. This is mainly an energy-dependent failure mechanism, namely the ESD pulse shape, duration and energy can produce power levels resulting in localised heating and eventually junction or lead melting, even though the voltage level is below that required to cause device degradation as well as functional failures. This can effect both performance and reliability. When this has taken place, then the “walking wounded” devicemay be more susceptible to both further ESD damage and also to damage by voltage surges and thermal degradation.”
[IEC 61340-5-2 User guide Annex DD clauses DD.2.2.1, DD.2.2.2 and DD.2.3]

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, and the product is completed and 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 and the product is returned to the customer with the problem unresolved.

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

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



One study indicated the cost to be:

- £7 Device
- £7 Device in board - £700
- £7 Device in board and in system - £7,000
- £7 Device and system fails - £70,000.

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 organisations consider all electronic components ESD sensitive. It is critical to be aware of the most sensitive item being handled in your factory. As electronic technology advances, electronic circuitry gets progressively smaller. As the size of components is reduced, so is the microscopic spacing of insulators and 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 and should be unpackaged and handled while grounded at an ESD protected workstation.

"IEC 61340-5-1 requires that the Organization mark ESDS assemblies and equipment in accordance with customer requirements. When marking is not specifically required the Organization shall determine whether a marking strategy is required. Markings on ESDS and ESD packaging materials exist to inform users that the devices or the devices within packages are susceptible to ESD.

Marking of hardware items (assemblies and equipment) can be accomplished by using the [ESD sensitivity] symbol. Marking of hardware is dependent on space available on the item itself as well as the environment the item will operate in and whether marking will hinder the operation of the item. Some hardware labels might contain nomenclature along with the symbol." [CLC/TR 61340-5-2 clause 4.9 Marking and 4,9.1 Marking of assemblies and equipment]

Most firms use the EN 61340-5-1 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 and increasingly tests an electronic device at higher and higher discharges until it fails, thus establishing the device's withstand voltage.

OHM'S LAW

At this point we should consider some basic physics:

Ohm's law is an extremely useful equation in the field of electrical/electronic engineering because it describes how voltage, current and resistance are interrelated.

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, and 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.

Resistance to ground (Rg) is a measurement that indicates the capability of an item to conduct an electrical charge (current flow) to an attached ground connection.

The measurement may be shown in various ways. Most commonly:

- 1 kilohm
- 1 kΩ
- 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

TYPES OF MATERIALS

Conductors

- Electrical current flows easily
- Can be grounded.

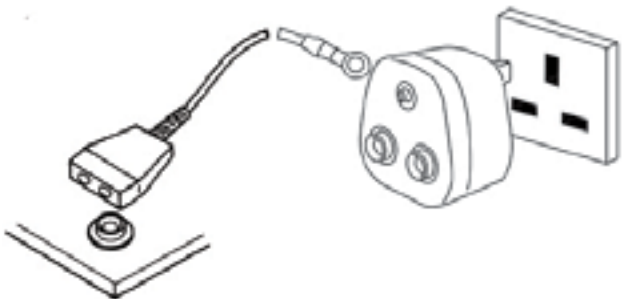
Materials that easily transfer electrons (or charge) are called conductors and are said to have "free" electrons. Some examples of conductors are metals, carbon, and the human body's sweat layer.

Grounding works effectively to remove ElectroStatic charges from conductors to ground. However, the item grounded must be conductive.

"In the electronics industry, smaller device geometries have resulted in higher density devices. ESD events can cause device damage such as metal vaporization, punch-through of thin oxide layers, or other failure modes. As mentioned earlier ESD events may or may not weaken devices so that they still pass production testing, but fail when installed in a customer's equipment."
[ESD Handbook ESD TR20.20-2008 section 5.3.6.1.2 ESD Effects]

"The next step in developing an ESD control program plan is to determine the part, assembly or equipment sensitivity level under which the plan is to be developed. The organization can use various methods to determine the ESD sensitivity of the products that are to be handled. Some of the methods include: assumption that all ESD products have an HBM sensitivity of 100 V; actual testing of ESD sensitive devices to establish the ESD sensitivity threshold using IEC 60749-26; referencing ESD sensitivity data in published documents such as manufacturer's published data sheets."
[CLC/TR 61340-5-2:2008 clause 4.1.2 Determination of part ESD sensitivity]

The other term often used in ESD control is dissipative which is 1 x 10^4 to less than 1 x 10^{11} ohms and is sufficiently conductive to remove ElectroStatic charges when grounded.



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

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, and glass. An insulator will hold the charge and cannot be grounded and “conduct” the charge away.

Both conductors and insulators may become charged with static electricity and discharge.

Grounding is a very effective ESD control tool, however, only conductors (conductive or dissipative) can be grounded.

Insulators like this plastic cup will hold the charge and cannot be grounded and “conduct” the charge away.

THINK OF STATIC ELECTRICITY AS GERMS AND CONTAMINATION!

Daily life has other examples of hidden enemies where careful procedures must be followed to regularly obtain positive results. One example is sterilisation, which combats germs and contamination in hospitals.

Damage caused by invisible and 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 defence against this invisible threat is extensive contamination control procedures including sterilisation.

“Dissipative materials provide charge dissipation. They also reduce areas of high charge concentration by allowing charges to spread out over the entire surface. Dissipative materials are not necessarily low charging. Insulative materials have a very high resistance and this limits the ability of the material to conduct current. In general, insulative materials can become highly charged through contact and separation with other materials. The dissipation of charge from insulative materials via grounding may take a long time (i.e. hours or weeks depending on the enviromental conditions). This makes insulative materials generally unacceptable for use near ESD sensitive products.” [CLC/TR 61340-5-2:2008 User guide clause 4.8.2.3 and 4.8.2.5]

“Determine the type of packaging system that is best suited for the intended application. The marketplace provides numerous options for packaging of electronic products for shipment. The initial consideration is to have low charging or static dissipative materials in contact with ESD sensitive items.

In some situations, packaging may be designed for reuse or return to the original supplier. In this way the package may be reused numerous times. The initial cost of these packages may be relatively expensive. However, if the appropriate collection and recycling system is used, the container may be the least expensive choice over time.
[CLC TR 61340-5-2 User guide Packaging clauses 4.8.3.3 and 4.8.3.3.1]

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 sterilisation in medicine. We must develop the same attitude towards ESD control and “sterilise” against its contamination. 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 measures against ESD.

For the hospital to sterilise most of the instruments is not acceptable; actually it may waste money. Each and every instrument needs to be sterilised. Likewise, it is not acceptable to protect the ESDS most of the time. Effective ESD control must occur at each and every step where ESDS is manufactured, processed, assembled, installed, packaged, labelled, serviced, tested, inspected, transported, or otherwise handled.

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 and discharges. Operators need training and to be vigilant that ESD control procedures are followed. In order for the ESD control programme to be effective, operators must be aware of the threat of ESD, and understand and adhere to the rules of controlling static electricity, and 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) ElectroStatic Discharge 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.

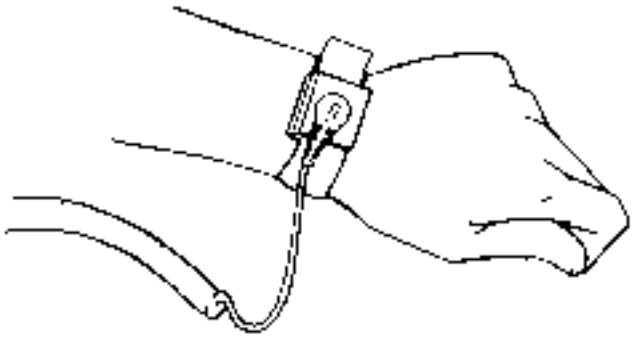
The ESD Protective Symbol identifies products designed to provide ESD control protection.

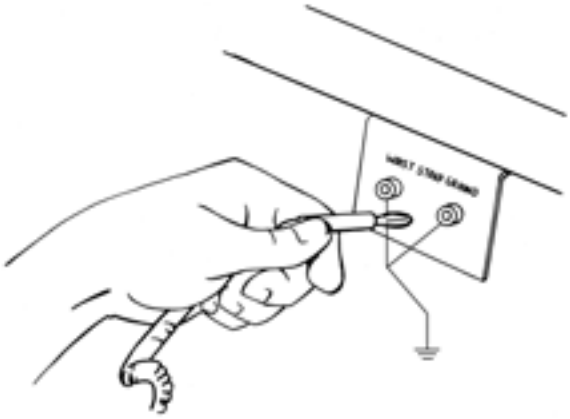
FUNDAMENTAL ESD CONTROL PRINCIPLES

- Ground all conductors including people
- Remove insulators, substitute with ESD protective versions, or neutralise with ionisers
- 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 defence against ESD, the most common personnel grounding device used, and are required to be used if the operator is sitting. The wristband should be worn snug to the skin with its coiled cord connected to a common point ground which is connected to ground, preferably equipment ground.





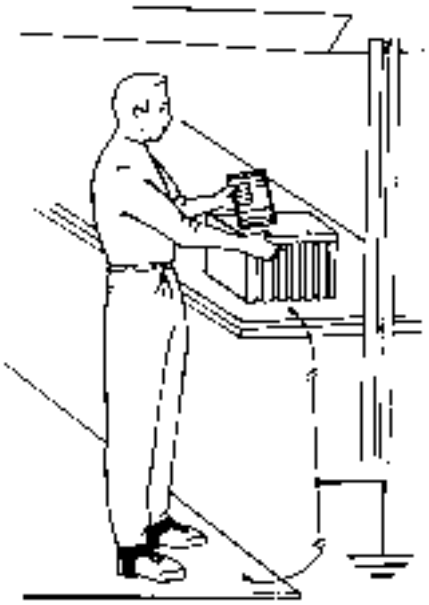
If you are not using a continuous or a constant monitor, a wrist strap should be tested while being worn at least daily. This quick check can determine that no break in the path-to-ground has occurred. Part of the path-to-ground is the perspiration layer on the person; an operator with dry skin may inhibit the removal of static charges and may cause a test failure.

Specially formulated lotion can solve this problem. 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, and 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 and 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.

The fundamental ESD control principles that form the basis of IEC 61340-5-1 are:
“electrically connecting all conductors in the enviroment, including personnel, to a known ground”
“Necessary insulators in the enviroment cannot lose their electrostatic charge by attachment to ground. Ionization systems provide neutralization of charges on these necessary insulators (circuit board materials and some device packages are examples of necessary insulators).”

“ESD protection can be achieved by enclosing ESD sensitive products in static protective materials, ... Outside an EPA, low charging and static discharge shielding materials are recommended.” [CLC/TR 61340-5-2:2008 User guide Introduction]



Both ESD footwear and ESD floor are required. Wearing ESD footwear on a regular, insulative floor is a waste of time and 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 and walks outside wearing ESD footwear, care should be taken not to get the ESD footwear soiled. Dirt is typically insulative, and 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 and 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 at least 1×10^4 ohms is recommended, and less than 1×10^9 ohms is required by EN 61340-5-1.

"Wrist straps should be tested periodically. The frequency of testing, however, is driven by the amount of usage, wear and ESD risk exposure that can occur between tests. For, example, what is the quantity of product handled between test periods? Typical test programs recommend that wrist straps that are used daily should be tested daily. However, if the products that are being produced are of such value that a guarantee of a continuous, reliable ground is needed then continuous monitoring should be considered or even required." [CLC/TR 61340-5-2:2008 User guide Wrist Strap clause 4.7.2.4.4 Test frequency]

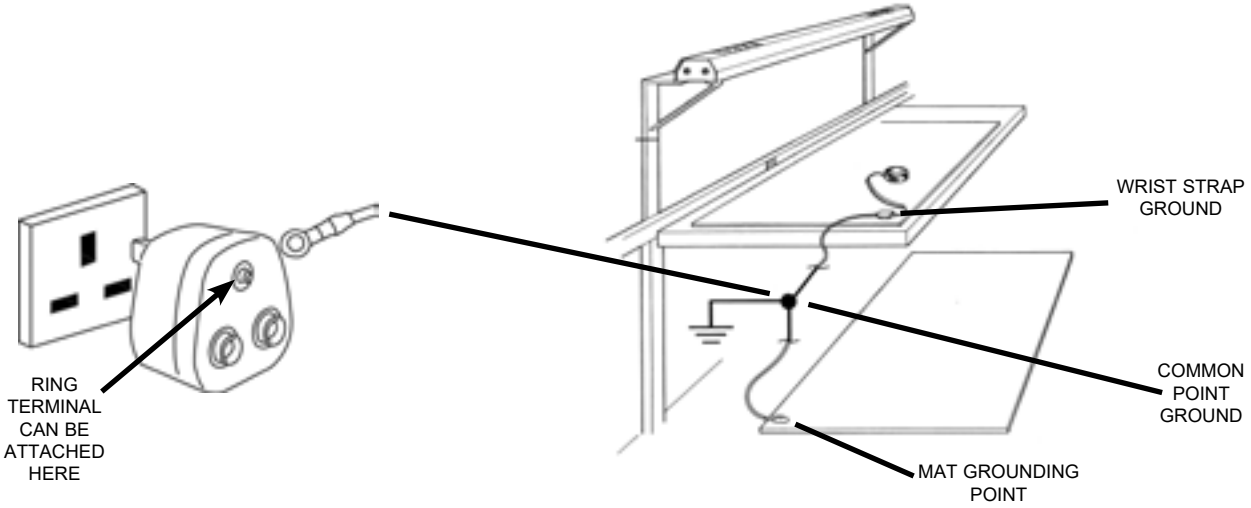
"ESD control footwear is designed to reduce body charge levels by supplying a conductive path from the body to the floor material. Heel or toe grounders should be worn on both feet to ensure effective use. Care should be taken to evaluate not only the footwear, but also the footwear/floor combination." [CLC/TR 61340-5-2:2008 User guide Footwear clause 4.7.4.3 Proper usage]

Best practice is that ground connections use firm fitting connecting devices such as metallic crimps, snaps and banana plugs to connect to designated ground points. Use of crocodile clips is not recommended.

Operators should ensure that the worksurface is organised to perform work, and that all unnecessary insulators and personal items are removed. Regular plastics, polystyrene foam drinking cups and packaging materials, etc. are typically high charging and 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. Then, when placed on the grounded ESD work surface, a discharge occurs.



"The protection of ESDS is accomplished by providing a ground path to bring ESD protective materials and personnel to the same electrical potential. All conductor and dissipative items in the environment, including personnel, shall be bonded or electrically connected to a known ground or common connection point [EBP earth bonding point]. This connection results in sharing of charge which equalizes the voltage across all items and personnel and eliminates the chances of an ESD event to ESD sensitive devices. Electrostatic protection can be maintained at a potential different from a "zero" voltage ground reference as long as all items in the system are at the same potential." [CLC/TR 61340-5-2:2008 User guide clause 4.4.1 Grounding/bonding systems Introduction]

"The first and preferred ESD ground is protective earth if available. In this case, the ESD control elements and grounded personnel are connected to protective earth"
[EN 61340-5-1 Edition 2.0 – 2016-05 ESD control program plan clause 5.3.2 Grounding/equipotential bonding systems]

"The most important functional consideration for work surfaces is the resistance from the top of the surface to the groundable point [Rgp]. This establishes the resistance of the primary path to ground for items placed on the surface. IEC 61340-5-1 has set a resistance to ground range for work surfaces of less than 1.0 x 10^9 ohms. However, it is sometimes necessary to use work surfaces that are much more conductive. This is allowed under IEC 61340-5-1 but the reason for using a more conductive work surface shall be documented in the ESD control program plan." [CLC/TR 61340-5-2:2008 User guide clause 4.7.1.2.5 Electrical considerations - Work Surfaces]

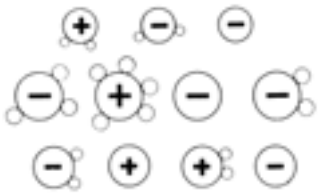
Per EN 61340-5-1 Edition 2.0 – 2016-05 "Table 3 EPA requirements the limit for Working surfaces, storage racks and trolleys is < 1 x 10^9 ohms Rg tested per IEC 61340-2-3" and per NOTE f "In situations where charged device model (CDM) damage is a concern a minimum point to point resistance limit of 1 x 10^4 ohms is recommended."

If the ESDS is removed from the presence of the ElectroStatic charge and grounded again, a second discharge may occur. (Ref. ESD Handbook, ESD TR20.20, section 2.7.5).

The worksurface must be maintained and should be cleaned with an ESD cleaner. Regular cleaners typically contain silicone, and 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 and check visually that the ground wire is attached.

IONISERS AND NEUTRALISATION

An ioniser creates great numbers of positively and negatively charged ions. Fans help the ions flow over the work area. Ionisation can neutralise 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 neutralise process essential insulators with ionisers. In addition, if a conductor is not grounded, it is an isolated conductor, and an ioniser is the only means to neutralise ElectroStatic charges on it.

Insulators, by definition, are non-conductors and therefore cannot be grounded. Besides neutralisation using ionisers, insulators can be controlled by doing the following:

- Keep insulators a minimum of 30.5 cm from ESDS items at all times, or
- Replace regular insulative items with an ESD protective version, or
- Periodically apply a coat of topical antistat.

When none of the above is possible, the insulator is termed “process essential” and therefore neutralisation using an ioniser should become a necessary part of the ESD control programme.

Examples of some common process essential insulators are a PC board substrate, insulative test fixtures, and 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 neutralisation. Ions are charged particles that are normally present in the air, and as opposite charges attract, charges will be neutralised over time.

A common example is a balloon rubbed against clothing and “stuck” on a wall by static charge. The balloon will eventually drop. After a day or so natural ions of the opposite charge

“Necessary insulators in the environment cannot lose their electrostatic charge by attachment to ground. Ionization systems provide neutralization of charges on these necessary insulators (circuit board materials and some device packages are examples of necessary insulators). The ESD hazard created by electrostatic charges on the necessary insulators in the work place is assessed to ensure that appropriate actions are implemented, according to the risk.” [EN 61340-5-1 Edition 2.0 – 2016-05 Introduction]

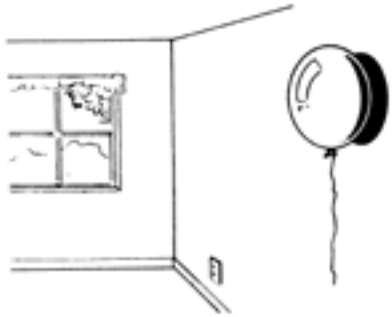
“All non-essential insulators and items (plastics and paper), such as coffee cups, food wrappers and personal items shall be removed from the workstation or any operation where unprotected ESDS are handled.

The ESD threat associated with process essential insulators or electrostatic field sources shall be evaluated to ensure that:

- the electrostatic field at the position where the ESDS are handled shall not exceed 5 000 V/m; or
- if the electrostatic potential measured at the surface of the process required insulator exceeds 2 000 V, the item shall be kept a minimum of 30 cm from the ESDS; and
- if the electrostatic potential measured at the surface of the process required insulator exceeds 125 V, the item shall be kept a minimum of 2,5 cm from the ESDS.

If the measured electrostatic field or surface potential exceeds the stated limits, ionization or other charge mitigating techniques shall be used. Some of the measurements should be taken at the lowest expected relative humidity experienced by the facility.”
[EN 61340-5-1 Edition 2.0 – 2016-05 Insulators clause 5.3.4.2]

that are in the air will be attracted to the balloon and will eventually neutralise the charge. An ioniser greatly speeds up this process.



Note: Ionisers require periodic cleaning of emitter pins and the offset voltage must be kept in balance. Otherwise, instead of neutralising charges, if it is producing primarily positive or negative ions, the ioniser will place an ElectroStatic charge on items that are not grounded.

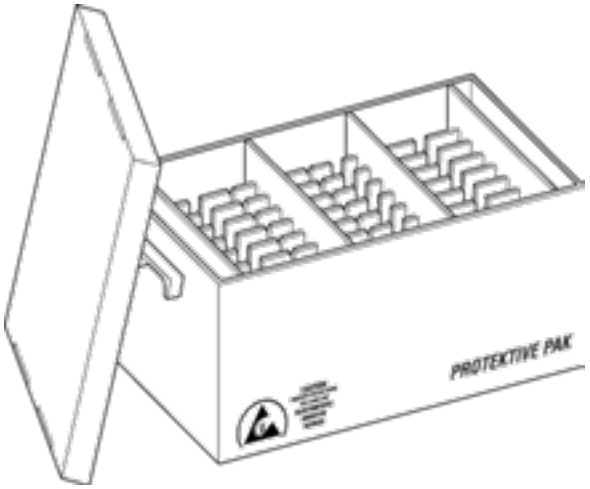
SHIELDING

The third fundamental principle of the ESD control system is to package ESD sensitive components and assemblies during storage or transportation outside the EPA enclosed in packaging that possesses the ESD control property of shielding. In shielding, we utilise the fact that ElectroStatic charges and discharges take the path of least resistance. The charge will be either positive or negative; otherwise the charges would balance out and there would be no charge. Charges repel and 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.

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

To complete the enclosure, make sure to place lids on boxes or containers, and close shielding bags. Packaging with holes, tears, or gaps should not be used as the contents may be able to extend outside the enclosure and lose their shielding as well as mechanical protection.



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

"The normal stable structure of the atom shows that unlike charges attract and like charges repel. Therefore, a separated charge will be self-repellant and will reside only on the surface of a charged item. If the item were a perfect insulator or perfectly insulated, a separated charge would remain indefinitely. Since there are no perfect insulators and it is impossible to have perfect isolation, charges tend to leak away to join opposite charges in the immediate environment thus returning the item to an electrically balanced state.

Taking all of the above into account, static electricity is the set phenomena associated with electrical charges on the surface of an insulator or insulated conductive body." [ESD Handbook ESD TR20.20-2008 section 2.3 Nature of Static Electricity]

"Electrostatic discharge shielding barrier or enclosure that limits the passage of current and attenuates the energy resulting from an electrostatic discharge such that the maximum energy from the 100 V human body model discharge is less than or equal to 50 nJ [nanojoules]." [EN 61340-5-1 clause 3.18.2 Definitions]

When ESD sensitive items are unpackaged from shielding bags or other containers, they should be handled by a grounded operator at an ESD workstation.

ESD WORKSTATIONS

An EPA might be one ESD workstation, an area that has been established to effectively control ESD. At an ESD workstation, we attempt to limit ElectroStatic charges by grounding all conductors (including people), removing all insulators (or substituting with ESD protective versions), or neutralising process essential insulators with an ioniser.

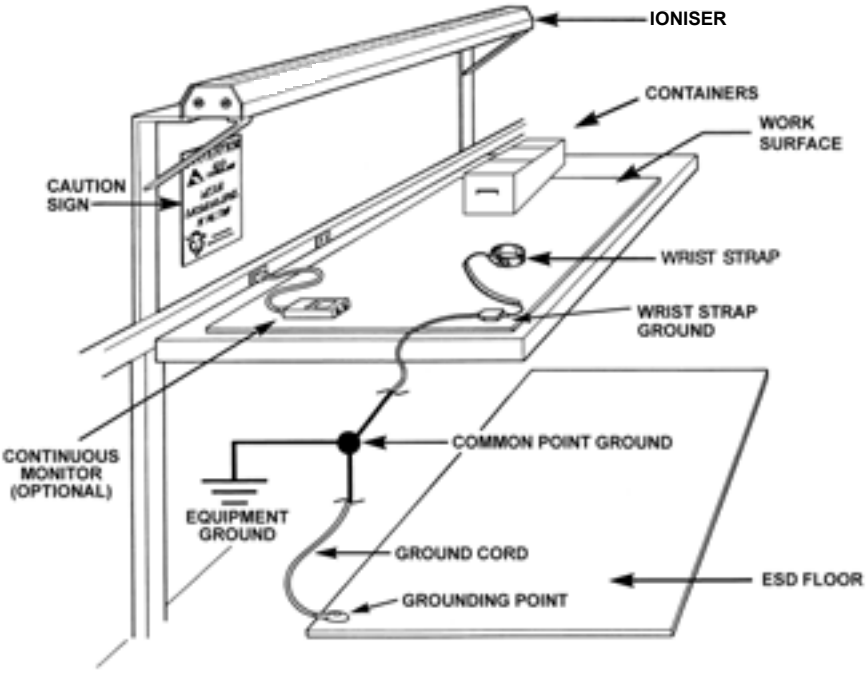
ADDITIONAL EPA ESD CONTROL ITEMS

In addition to conductive and dissipative worksurfaces, personnel grounding devices and ionisers, your company may provide a variety of additional ESD control materials.

The proper use of these materials will enhance your company's ESD control programme.

Regular versions of these products have been changed to be low charging and/or groundable:

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



"An ESD protected area (EPA) is an area that is equipped with the ESD control items required to minimize the chance of damaging ESD sensitive devices. In the broad sense, a protected area is capable of of controlling static electricity on all items that enter that work area. Personnel and other conductive or dissipative items shall be electrically bonded together and connected to ground (or a common connection point when a ground is not available) to equalize electrical potential among the items. The size of an EPA can vary greatly. A protected area may be a permanent workstation within a room or an entire factory floor encompassing thousands of workstations. A protected area may also be a portable worksurface or mat used in a field service situation." [CLC/TR 61340-5-2:2008 Use guide clause 4.6 Protected areas (EPA)]

HANDLING CLASS 0 ESD SENSITIVE ITEMS

SPECIAL ATTENTION

HBM CLASS 0

Handle Only Using Class 0 ESD Control Precautions

CLASS ZERO

EN 61340-5-1 guides a user to enact an ESD Control Programme to handle ESD sensitive items with a withstand voltage of 100 volts Human Body Model (HBM) or greater and 200 volts Charged Device Model (CDM) or greater. The updated standard ANSI/ESDA/JEDEC JS-001-2011, For Electrostatic Discharge Sensitivity Testing Human Body Model (HBM) - component level table 3 has divided the class 0 classification into two withstand voltage levels with class 0A being less than 125 volts sensitivity, and class 0B being 125 to less than 250 volts.

Per EN 61340-5-1 Scope “ESDS with lower withstand voltages may require additional control elements or adjusted limits”. If you handle class 0A ESDS items, to decrease the probability of ESD damage, additional precautions may be required including additional and/or more stringent technical requirements for EPA ESD control products, increasing redundancies, and more frequent periodic verifications or audits. Additionally, ESD control process systems should be evaluated as to their performance as a system. You will need to understand how the technical elements in use perform relative to the sensitivity of the devices being handled. Thus, tailoring the process to handle the more sensitive parts.

For example: If the person/footwear/flooring personnel grounding system allows a person’s body voltage to reach say 80 volts and a 50 withstand voltage item gets introduced into the process, you will either have to allow only handling via wrist straps or would have to find a way to modify the footwear/flooring performance to get peak voltages below the 50 volts threshold. Class zero workstations may be identified, and additional measures may include:

IONISATION

- More stringent removal of non-essential items from the workstation
- Ionisation to reduce charges on isolated conductors like devices on PCB’s
- Ionisation to reduce induction charging from process essential insulators
- More stringent offset voltage (balance) and/or faster decay times
- Use of ionisers with feed-back mechanisms and out of balance alarms.

GROUNDING

- Use continuous monitors to verify proper grounding of operator and worksurface
- Specify more stringent resistance technical requirements such as 1×10^6 to $< 1 \times 10^9$ ohms dissipative worksurface
- Require conductive ESD floor (Per ANSI/ESD STM7.1 $< 1 \times 10^6$ ohms)
- Require more reliable ESD footwear such as full coverage foot grounders (as opposed to heel grounders)
- Require improved grounding (using positive mechanical attachments) of carts, shelves, and equipment to ground
- Require dissipative material for all fixtures.

SHIELDING

- Use ESD smocks to shield ESD sensitive items from charges on operator clothing
- Use ESD packaging with shielding properties to store and transport ESDS both within and outside the ESD protected area.

Other steps may include minimising electrostatic charge generation, converting production supplies to ESD protective versions, or treating with topical antistat, requiring dissipative material, increasing training, and frequency of compliance verification periodic checks.

ESD BASICS (Supervisor Level) QUIZ - True or False

1		An example of ElectroStatic Discharge or ESD is the zap one sometimes feels after walking across carpeting and touching a metal doorknob.
2		Static charges are generated when two surfaces contact and separate. Electrons move from one surface to another causing an imbalance. The surface with a deficiency of electrons has a positive charge and the surface with an excess of electrons has a negative charge.
3		ElectroStatic charges eventually will come into balance, but when this occurs suddenly an ESD or ElectroStatic Discharge event occurs. However, this event cannot melt electronic circuitry.
4		A powerful example of an ESD event, creating lots of heat and light, is lightning.
5		Conductors are a type of material where electrical current flows easily so it can be grounded. Examples of conductors include plastics and Styrofoam cups.
6		Insulators are a type of material where electrical current does not flow easily that cannot be grounded. Examples of insulators include metals and people.
7		A person walking across a carpeted floor can generate a voltage, but not greater than 100 volts of ElectroStatic charge on their body.
8		Charges on a person frequently discharge, but for the person to feel the zap, a discharge must be about 2,000 volts.
9		In manufacturing handling electronic components, ESD is the hidden enemy as there can easily be damaging ElectroStatic Discharges that a person cannot see or feel.
10		Passing an inspection test means that the ESD sensitive item (ESDS) has experienced a catastrophic ESD failure.
11		Passing an inspection test means that the ESD sensitive item (ESDS) has not experienced a latent ESD defect.
12		Although passing all inspections in the factory, ESDS items having latent defects and failing in the field can be very expensive in warranty expense, field service repairs, and loss of customer satisfaction.
13		Manufacturing ESD sensitive items without proper ESD control is like a physician conducting surgery on you without following sterilisation procedures.
14		A person can be charged, and as a conductor, should be grounded at the ESD protective workstation. Always be grounded when handling unpackaged ESD sensitive items; and always wear a wrist strap when seated at an ESD protected workstation.
15		Make sure to always ground insulators.
16		Even if it adversely affects the quality of the products you are working on, allow strangers into the work area and handle products as they please.
17		If the air flow of the ioniser bothers you, it's OK to direct it away from the products you are working on.
18		Regular plastic bags are high charging insulators and should not be permitted in an ESD protected area.
19		ESD shielding bags, if closed, will keep ElectroStatic charges on the exterior of the bag, and being dissipative, the charge will be removed when handled by a grounded person or placed upon a properly grounded ESD worksurface.
20		Wrist straps and ESD footwear should be tested at least daily, and while wearing them. You should notify your supervisor if a failure occurs.
21		ESD foot grounder grounding tabs should be cut off.
22		ESD smocks shield ESDS items from charges on your clothing. Most clothing is insulative and these charges cannot be removed via your wrist strap. Make sure to button up ESD smock covering all clothing.
23		The ESD Association understands that high charging personal items should be allowed in an ESD protected area, even if they might damage products.
24		Only trained or escorted people should be allowed in an ESD protected area.
25		Use ESD packaging that has discharge shielding properties to store or transport ESD sensitive items outside an ESD protected area.

ESD BASICS (Assembler Level) QUIZ

Please answer the following questions by circling the correct letter.

1. ElectroStatic charges are generated:
A. By heat
B. By high humidity
C. When 2 surfaces contact then separate

2. When a "zap" is felt by a person, the voltage of the ElectroStatic Discharge (ESD) has to be about:
A. 200 volts
B. 2,000 volts
C. 20,000 volts

3. The first line of defence against ESD is:
A. The ioniser
B. The foot grounder
C. The wrist strap

4. Some of today's ESD sensitive devices can be damaged by as little as:
A. 100 volts
B. 800 volts
C. 3,000 volts

5. If not using continuous monitors, wrist straps should be tested at least:
A. Daily
B. Weekly
C. Monthly

6. When transporting or storing ESD sensitive devices outside the ESD protected area, the devices should be in packaging that includes:
A. Grounding
B. Shielding
C. Ionising

7. Materials that are non-conductors cannot be grounded; they are also called:
A. Dissipative
B. Conductors
C. Insulators

8. To neutralise ElectroStatic charges on insulators, use:
A. Ground cords
B. Conductive mats
C. Ionisers

9. An ESD protective worksurface mat should be:
A. Grounded
B. Clear of non-essential insulators
C. Cleaned only with an ESD cleaner
D. All of the above

10. Wrist strap band should be:
A. Snug on skin around the wrist
B. Removed if a nuisance
C. Placed over shirt sleeve

11. Foot grounders, if used, should be tested at least daily; the grounding tab should be:
A. Cut off
B. Placed in shoe under your foot
C. Tied around your finger

12. An ESD smock shields product you are working on from charges on your clothing. Front panels should be:
A. Closed covering all clothing on torso
B. Left wide open
C. Tied calypso style

13. In the workplace, ESD is a hidden enemy, you may want to think of it as a form of:
A. Combustion, like where there's smoke there's fire
B. Corruption, like money and politicians
C. Contamination, like germs in a hospital operating room

14. Insulators, not needed to do your job, such as drinking cups, regular tape, picture frames, radio enclosures, etc. should be:
A. Allowed to induce charges on ESD sensitive products
B. Colour coded for identification
C. Removed from the ESD protective workstation

15. ESD control products are often regular products that have at least one ESD control property added. Examples are:
A. ESD smocks
B. ESD packaging, bags and boxes
C. Dissipative document holders
D. All of the above

For quiz answers go to:

www.DescoIndustries.com/pdf/assembler.pdf

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see Technical and Resources tabs

"Process monitoring (measurements) shall be conducted in accordance with a compliance verification plan that identifies the technical requirements to be verified, the measurement limits and the frequency at which those verifications must occur. The compliance verification plan must document the test methods used for process monitoring and measurements… Compliance verification records shall be established and maintained to provide evidence of conformity to the technical requirements. The test equipment selected shall be capable of making the measurements defined in the compliance verification plan."
[IEC 61340-5-1 clause 5.2.3 Compliance verification plan]

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