STATIC ELECTRICITY

Static electricity, its effects and its control, can be better understood by becoming familiar with the theory of static generation. As dictated by the molecular theory of matter structure, each molecule of a body is composed of negative and positive charges. Negative-charged electrons orbit around a nucleus which contains positive charges. In order to maintain a balanced or uncharged molecule, the sum of the orbiting electrons must equal the sum of the positive charges in the nucleus. The negatively charged electrons are travelers, and move freely about. When two objects or materials are brought into intimate contact with each other, the negatively charged electrons, especially the valance electrons (those farthest from the nucleus), move freely back and forth from molecule to molecule. As the materials are separated, one loses electrons and becomes positively charged; the other material gains electrons and assumes a negative charge.

As an example, two pieces of plastic film when frictioned and held together by hand, will have a net positive charge (lacking electrons). This can be observed by checking them with an electrostatic measuring device. The missing electrons have been absorbed by your body and will eventually drain off to ground. As the two pieces of plastic are separated, one assumes a negative charge while the other, having lost electrons, assumes a positive charge. This can also be observed by measuring the static charge voltage on each with the measuring device. The greater the pressure of contact (resulting in greater friction), the easier it becomes for the electrons to move freely about. Also, the faster the speed of separation, the greater the charge.

Classification of Materials

Materials are divided into two basic classifications: insulators and conductors. Within an insulator, the movement of electrons is limited within itself and, when connected to ground, there is no movement or flow of electrons. An insulator may contain different charge levels, with a deficiency of electrons in one area and an abundance of electrons in another. In a conductor, the electrons are free to move within itself, resulting in a charge of the same level throughout the conductor. When the conductor is connected to ground, there is a movement of electrons with respect to ground.

Earth ground is an infinite source of and receptacle for electrons, with electrons moving freely in both directions. This can be more graphically shown by observing the Triboelectric Series. The Triboelectric Series places all materials in the order of their ability to gain electrons with respect to other materials in the series. It is now understood that simply attaching a conductor to a good ground allows electrons to flow in both directions, thus preventing the accumulation of electrostatic charge. The process of neutralizing insulators is not quite as simple, however. There are two common methods: the conductivity method and the replacement method.

Conductivity Method

An electrically conductive material, when connected to ground, will automatically discharge and become neutral, since it cannot maintain differences of static charge levels on any of its parts. Therefore, if a conductive material is permanently attached to ground, an electrostatic charge cannot develop. It now becomes evident that making an insulator conductive would allow static charges to be neutralized by simple grounding techniques. When advantageous, there are three methods that can be employed to make an insulator conductive. They are: Humidification, Antistatic Chemical Coatings, and Internal Antistats.

Humidification

Electrostatic charges normally cause fewer problems during the summer months than in the winter because of higher humidity. During higher humidity conditions, many materials tend to absorb moisture and become somewhat electrically conductive. Some materials, being non-hygroscopic, do not have the ability to absorb moisture; to achieve the same effect, it would be necessary to raise the humidity to such a level that moisture would collect on the surface of the material. Unfortunately, this impractical situation would be detrimental to most manufacturing operations and would eventually lead to rust and corrosion of metal parts and machinery.

Antistatic Chemical Coatings

Antistatic chemical coatings provide a means for forming an electrically conductive surface on a nonconductive material or object. This treated surface attracts and absorbs moisture from the air, forming an electrically conductive layer.

Chemical coatings, however, sometimes tend to present manufacturing problems. The application of chemical coatings generally requires an additional operation and there may be areas where the coatings themselves may cause less than desirable effects.

There are many antistatic chemicals on the market today. These chemicals are available in aerosol sprays and in liquid concentrations which require dilution. The liquid form is applied by dipping, wiping or spraying.

Internal Antistatic Agents

Internal antistatic agents are similar to antistatic chemical coatings in effect, but are internal rather than applied to the surface. These antistatic agents are incorporated into insulating plastic materials prior to molding or extrusion. These internal antistats constantly migrate to the surface of the plastic material. This allows attraction of moisture from the air and renders the surface slightly conductive. However, as the antistat continues to leech out and off, the material may reach a point where the antistat properties have been lost and the material then changes to a partial insulator, losing its ability to discharge static charges to ground.

Carbon Loading

Carbon loading is another method of making an insulator conductive. Carbon particles are compounded with plastic materials prior to extruding or molding. This material then becomes electrically conductive rather than antistatic. This method is the most widely used for handling the problem of static discharge in sensitive electronic components.

Replacement Method

The second method of neutralization is the replacement method. If missing electrons can be replaced, positively charged parts can be made neutral. If molecules can be made to give up excess negative electrons, this part can be made neutral as well. The method of supplying these particles (called ions) for purposes of neutralization is splitting air molecules into positive and negative parts. This is called ionization.

There are two basic types of equipment used to produce ionization:

1. Radioactive static eliminators usually use elements such as polonium, Americium or radium to bombard the air molecules with high speed particles emitted by these radioactive elements. Static eliminators using these elements are not considered extremely efficient devices.
2. High voltage electrical static eliminators usually consist of points to which high voltage is

applied in proximity to a ground reference. The voltage across the gap ionizes the air. When a charged material passes through the ionized field, it becomes neutral by absorbing or giving up the proper number of electrons to neutralize itself. The electrically powered static eliminators are considered far more efficient than their radioactive counterparts.

Effects on Manufacturing and Personnel

As previously mentioned, a conductive object when connected to ground will readily bleed its electrostatic charge to ground. Since the human body is conductive, an electrostatic charge can be removed by simple grounding. If the person performing an operation is not adequately grounded and an electrostatic charge develops from body movement, the dissipation of the stored static charge to a part or component is most likely. As you can well understand, a floating conductor can develop a sizeable electrostatic charge (10 to 30 KV) and, when coming in contact with a grounded object, can dissipate this charge in the form of a high voltage arc or an electrostatic discharge (ESD). This can have a detrimental effect on sensitive electronic parts. In the case of IC's, the dissipation of an electrostatic charge can either degrade or destroy the insulation layer of the component.

Generally, in industry, the accumulation of static charges within the human body does not cause adverse effects to the manufacturing operation, merely an annoying shock to the individual. But in hazardous environments, static discharge in the form of arcing may cause a devastating result: fire and explosion. The importance of proper personnel grounding can now be realized. As a protection to the operator and his environment, controlled resistance grounding techniques must be used.

Clothing made of synthetic materials such as Dacron, Nylon, Rayon, etc. can be a source of static build-up within the human body. As a person moves about normally, there is constant contact and separation of clothing from the body. This, coupled with synthetic soled shoes or walking on a carpet or vinyl floor, places the individual in an ideal situation to build up and hold a sizeable electrostatic charge. For best results, operators should wear cotton clothing covered with an antistatic garment.

Antistatic garments generally are somewhat conductive in nature, and in effect, provide a type of "screen" to aid in reducing strong static fields which could induce damaging static charges on nearby sensitive devices. The antistatic garment should cover all static-generating clothing where possible, and should at some point make contact with the person's body to provide a resistive path to ground, allowing a path for some static charges to drain from the garment. Conductive wrist straps normally are used to form the resistive path between the person's body and ground.

There are three basic types of antistatic garments available on the market today. All have been proven effective in controlling static charges on clothing, but some types do have limitations and disadvantages.

One type of antistatic garment consists of cotton or synthetic materials treated with an antistatic chemical agent. This agent is usually applied in the final rinse cycle during laundering. The effectiveness of this type of garment is somewhat dependent upon ambient relative humidity. The antistatic agent withdraws moisture from the air which collects on the fabric, forming a thin film. This film becomes a conductive path which helps to dissipate or effectively drain off static charges. This garment normally remains effective between washings; however, it must be retreated with the agent each time it is laundered. In addition, the agent can be transferred by physical contact or rubbing and could conceivably be considered a contaminant when working with electronic components requiring surfaces with extremely high values of resistance and in clean-room conditions where contamination presents a severe problem.

The second type of antistatic garment is made of conductive plastic, basically the same carbon-impregnated material used in conductive bags and other products. This material provides good control of static charges regardless of relative humidity conditions, but is somewhat limited in its use as a garment because of its stiffness and the non-breathing characteristics of the plastic material.

The third type is manufactured from a unique fabric blend of 65 percent polyester, 34 percent cotton and 1 percent stainless steel fiber. The stainless steel fiber is woven into the fabric during manufacture and thus is an integral and permanent part of the finished garment. Because of this unique fabric design, the static control properties are very good and will last the life of the garment. These garments are not appreciably affected by relative humidity and require no chemical treatment during laundering.

Complete Protection — The Total Concept

Complete static control requires a total concept. Protecting personnel, or protecting against electrostatic discharge by personnel is only one part of the overall concept. For complete protection, other items that must be taken into consideration are:

Conductive Work Surface. The surface of the work station should be covered with an electrically conductive plastic sheet which has been properly grounded.

Conductive floor mats. To protect the work area from individuals who might enter with a static charge, the floor should be covered with an electrically conductive plastic floor mat. This will insure that any electrostatic charge will drain off before coming in contact with a sensitive device. This, of course, is true only if there is a path from the operator to the grounded mat.

Wrist Straps. A conductive wrist strap properly grounded is essential to drain the static charges which might accumulate on the operator. The wrist strap is the single most important protective device for effective static control. Caution should be taken to insure that the proper device is used. A series resistance of from ¼ to 1 meg is essential to protect the operator from possible shock hazard.

Seats or stools. Conductive chairs should be used and placed on an electrically conductive floor mat. If the seat is made of fabric, it should be covered with a conductive plastic or antistatic cloth providing a good path from the seat to the ground mat.

Conductive Tote Boxes & Trays. Do not use plastic boxes or trays that are not electrically conductive or antistatic in nature. Polyethylene tote boxes and trays can develop a sizeable static charge so should be avoided. To insure complete protection, conductive tote boxes and trays should be used.

Conductive Foam. Conductive foam should be used as carriers for sensitive devices. When the leads are placed in the foam, they are protected against static damage because all of the leads are at the same potential.

Conductive Bags. For shipment of static sensitive devices through the work areas as well as to customers, electrically conductive plastic bags will protect the devices from static damage. However, it is essential that when removing the devices from the bags, the bags as well as the person removing the parts be thoroughly grounded.

Soldering Irons. If the tip of the soldering iron is isolated from ground, a static charge may develop. Make sure the tip is electrically or mechanically grounded.

Solder Suckers. Do not use plastic solder suckers, as they generate high electrostatic charges and may arc to the device lead.

Masking Tape. Masking tape used to cover circuit board terminals during wave soldering should be removed very slowly. The separation may result in a static charge which causes a difference in potentials between terminals resulting in an arc-over. The tape should be removed under the influence of ionized air. Another precaution is not to use polyethylene sheeting to cover test equipment or as a dust shroud over storage trays. Polyethylene develops tremendous static charges when frictioned, and can electrostatically charge ungrounded conductors several feet away. It is wise to remove all plastic from the work area, substituting electrically conductive material where possible.

Ionized Air. Next to the wrist strap, the second most important safeguard for the workstation is the use of ionized air. To prevent any unwanted static build-up, simply position an electrical ionizing air device so that it gently blows ionized air across the work area. Any static charge coming in contact with the air stream will automatically be neutralized. Also, while working in the ionized field, no new static charges can develop. Special ionized air devices are available for laminar flow work benches as well as for clean rooms. For the simultaneous cleaning and neutralizing of parts or assemblies, ionizing air guns should be used instead of standard compressed air guns.

Electrostatic Measuring Devices. In order to ensure complete protection against static, it is important that a good quality static measuring device be available on site. A quality instrument detects and measures the voltage and field strength associated with static charges on objects and materials. This instrument is particularly useful in locating and analyzing static problems and aiding in proper positioning of static control equipment and devices. Effectiveness of static eliminators can be analyzed, and materials may be tested to determine their chargeability and rate of discharge.

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