Improving static control awareness

Electrostatic discharge (ESD) has killed more semiconductor products than any destructive tests. But the awareness is now high and the products to suppress static are legion

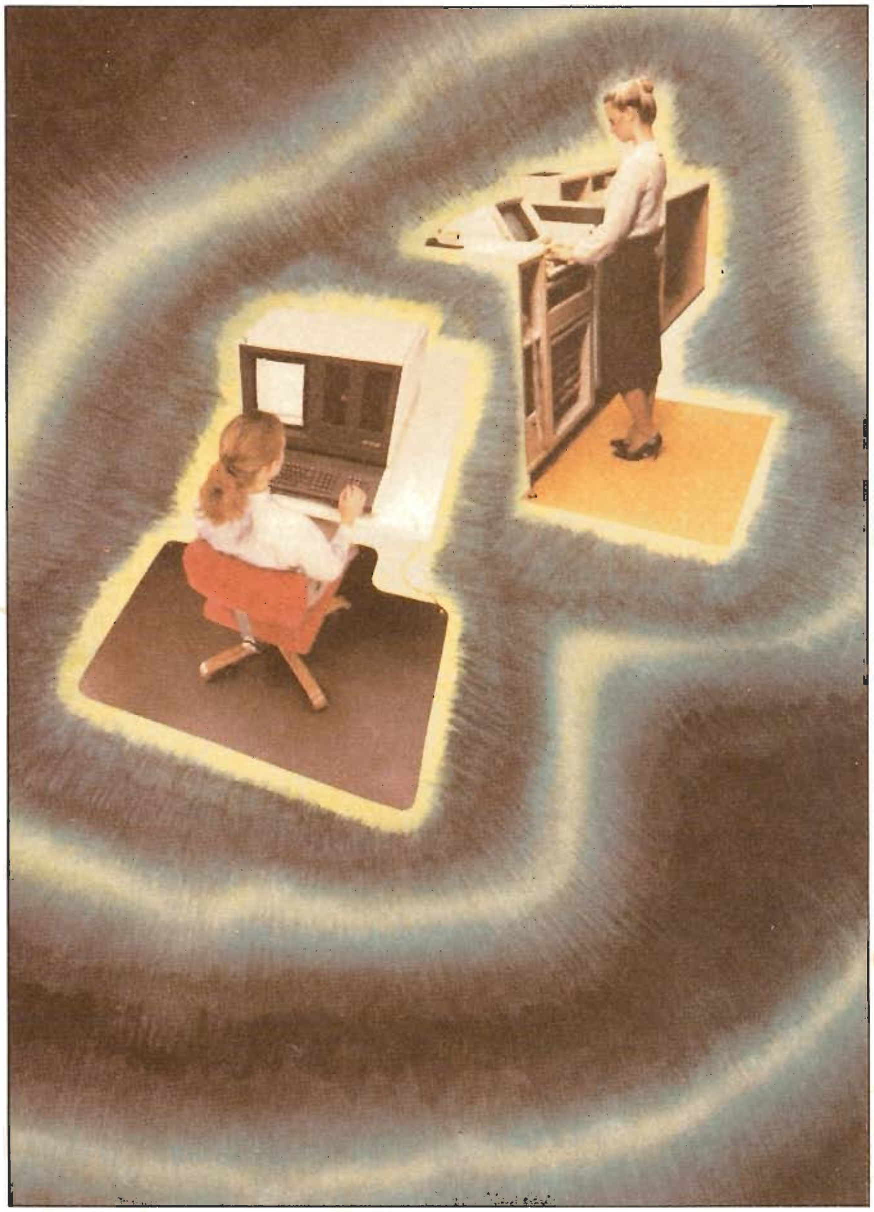
By Peter Green, Market Manager, Static Control Systems, 3M Canada Inc.

The effect of static charges on microelectronic components is no longer a matter of speculation. Device manufacturers, printed circuit board assemblers, equipment manufacturers, and to some extent equipment users, have all become aware of the tremendous losses associated with damaging static charges.

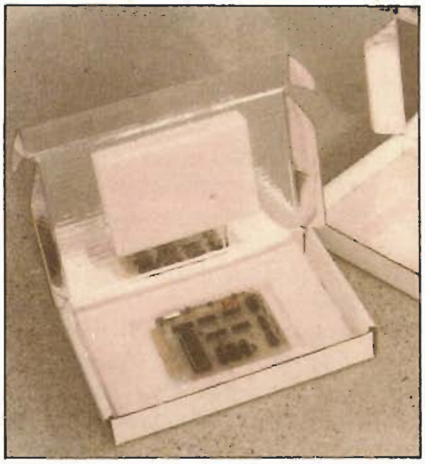
Industry was initially slow to recognize the need to control ESD, but the trend to smaller, faster microelectronic devices that consume less power has caused static control to become an area for critical concern. It has become so important in the manufacturing sector that it may become a limiting factor in the drive to achieve greater packaging densities and combine functions on single chips.

Arriving at this level of awareness has not been easy. Static charge levels needed to damage most components are below the threshold of human perception *(Table 1)*. Conducting the research and gathering the data needed to identify and quantify the results of electrostatic damage has been a difficult and lengthy task.

Even today, new research is helping



Static



The RSC or regular slotted carton when shielded provides both physical protection and static shielding.

to establish better control of the ESD phenomenon. New and better shielding methods and materials, better testing procedures and more critical circuit and component design are being used to wage the battle on many fronts.

Static can be costly

There is good reason for concern. 3M static control analysts point out that a 0.5% device failure rate becomes a 40% system failure rate on systems with five boards containing 20 devices each. This results in escalating costs to repair and replace at the field level, and perhaps a corresponding loss of credibility in a competitive marketplace, *(Table 2)*.

The hard or catastrophic failure of a microelectronic component is easy to isolate and repair. However, soft or latent degradation is far more difficult to identify. Some manufacturers claim there are 10 degraded components for every one damaged to immediate failure. And it should be noted that 90% of the ESD problems in field applications are the result of component degradation, rather than a hard failure.

A recent study of various devices showed that voltage strikes at 25% of the device's rated destructive level, can seriously soften the "knee" of the current/voltage characteristic. (MIL-STD-883C, Test Method 3015-2).

Systems approach

Many companies are finding that success in dealing with electrostatic discharge depends on adopting a systems approach to the problems. This involves making sure that the various static control products being used complement each other and that all elements of the organization are equally effective. Any one product might have impressive technical specifications, but it is very important that it work well in conjunction with other products in order that it perform to the fullest extent of its capabilities.

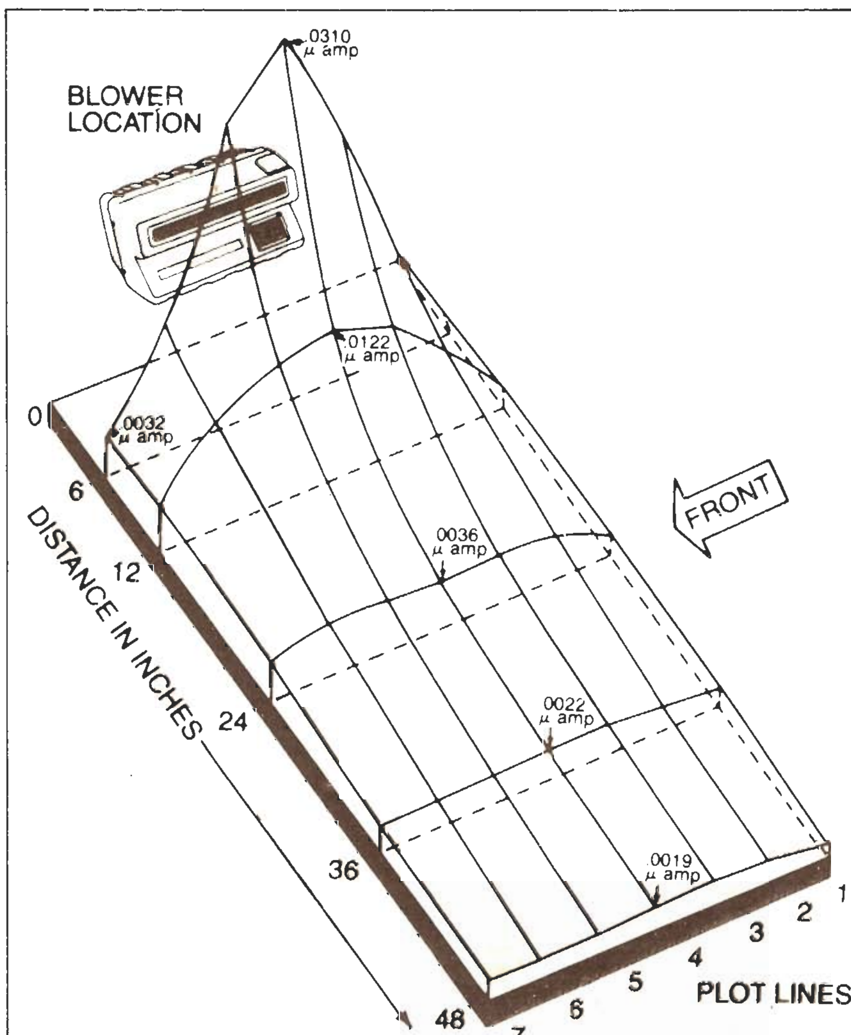
It is, of course, important to control static charges on non-conductive surfaces as well as conductors. Paper, plastic and styrofoam are examples of non-conductors found in abundance. Technology to manage this has been used for many years. The printing, plastic film and sheet fabricating, and the photoprocessing industries are examples of those who have applied the methods successfully.

Neutralizing the static charges is achieved by production of free positive and negative ions from a nuclear or high voltage electrical source. Usually a non-turbulent airflow is used to distribute the ionized environment. The same principle can be used to combat charges on non-conductors in the electronic manufacturing workplace. An ionizing air-blower installed at a workstation, for example, can complete the ESD control system here, and in addition contribute to worker comfort with a gentle, warm airflow at the same time.

Next priority

Even 100% static control during manufacture does not mean an end to the problem, however. Protective measures must extend beyond assembly

Ionized air blower effectively sweeps static away. Illustration shows ionization current pattern. The unit relating to these characteristics is a 3M 911 with nuclear static eliminator element.



to encompass transport, storage, shipping, field service work and end use.

Preventing static damage from occurring after manufacture, along with ESD-related field failures, becomes the next priority. To achieve this, the same level of awareness must be promoted among field service organizations and equipment operators alike. Material suppliers and electronic equipment manufacturers can each benefit from this process.

Protect during shipment

Often overlooked is the protection that should be afforded the ESD-sensitive components while they are being transported from the manufacturing facility to the next step in the distribution chain.

Protection must be both physical and static shielding. The former can be accomplished in a number of standard types of shipping containers. By far the most frequent method, regular slotted cartons (RSC) usually provide physi-

ESD Susceptibility of Various Electronic Devices

Device Type	Range of ESD Susceptibilty (Volts)
VMOS	30 to 1800
MOSFET	100 to 200
GaAsFET	100 to 300
EPROM	100
JFET	140 to 7000
SAW	150 to 500
Op Amp	190 to 2500
CMOS	250 to 3000
Schottky Diodes	300 to 2500
Film Resistors (Thick, Thin)	300 to 3000
Bipolar Transistors	380 to 7000
ECL (PC Board Level)	500 to 1500
SCR	680 to 1000
Schottky TTL	1000 to 2500

Source: Dow Chemical

Table 1

Typical Discharge Times

Object centered in 2′ x 4′ work area

Object	Capacitance (pico farads)	Voltage (kilovolts)	Neutralization Time (seconds)
Coffee cup (styrene)	10	3	8.3
Plastic box (2"x3"x⅞"	4	5	5.6
Cardboard box (2"x5½"x¾")	4	5	11.1

Table 3. *Typical discharge times using an ionized air blower for non-conductive objects. Watch for those styrene coffee cups!*

The static-safe work area is capable of controlling static charge on conductive objects, non-conductive objects and people

cal protection from puncturing. Some form of interior wrapping also is required to reduce the damage from vibration.

Triboelectronic charge damage can be easily prevented by using some form of antistatic or conductive wrapping or filler. Care must be taken to ensure that the material used is conductive enough to provide true antistatic properties.

Two other forms of electrostatic damage, direct current discharge or voltage field effects, need another form of protection—a static shield or Faraday cage. To achieve this, a conductive shielding material can be coated or laminated to the carton surface. Alternatively, the ESD-sensitive components can be simply shipped in the same static shielded bag that was used to transport them from the assembly area.

Some companies are considering the use of a static shielding bag inside a shielded shipping container lined with antistatic foam. Although some may consider this double or even triple protection, consideration should be given to the handling procedure at the destination. ESD-sensitive components remain so always, regardless of the point reached in the distribution cycle. As a result, protection must be afforded in case the component is removed from its shipping container before reaching a static-safe work area.

Large field service industry

The majority of electronic equipment purchased in this country is imported, and maintaining and repairing it has become in itself a large Canadian industry. Many companies have their own captive service departments, a good example being the telephone operating companies. Others are contracted to service certain equipment on an exclusive basis. Numerically, the largest group are the independent field service organizations.

In every case, field service can either help or hinder the effort to prevent ESD-failure. If static control procedures are not implemented here, original efforts by the manufacturer can be nearly neutralized. On the other hand, simple precautionary measures can enhance manufacturers' ESD programs and significantly reduce prema-

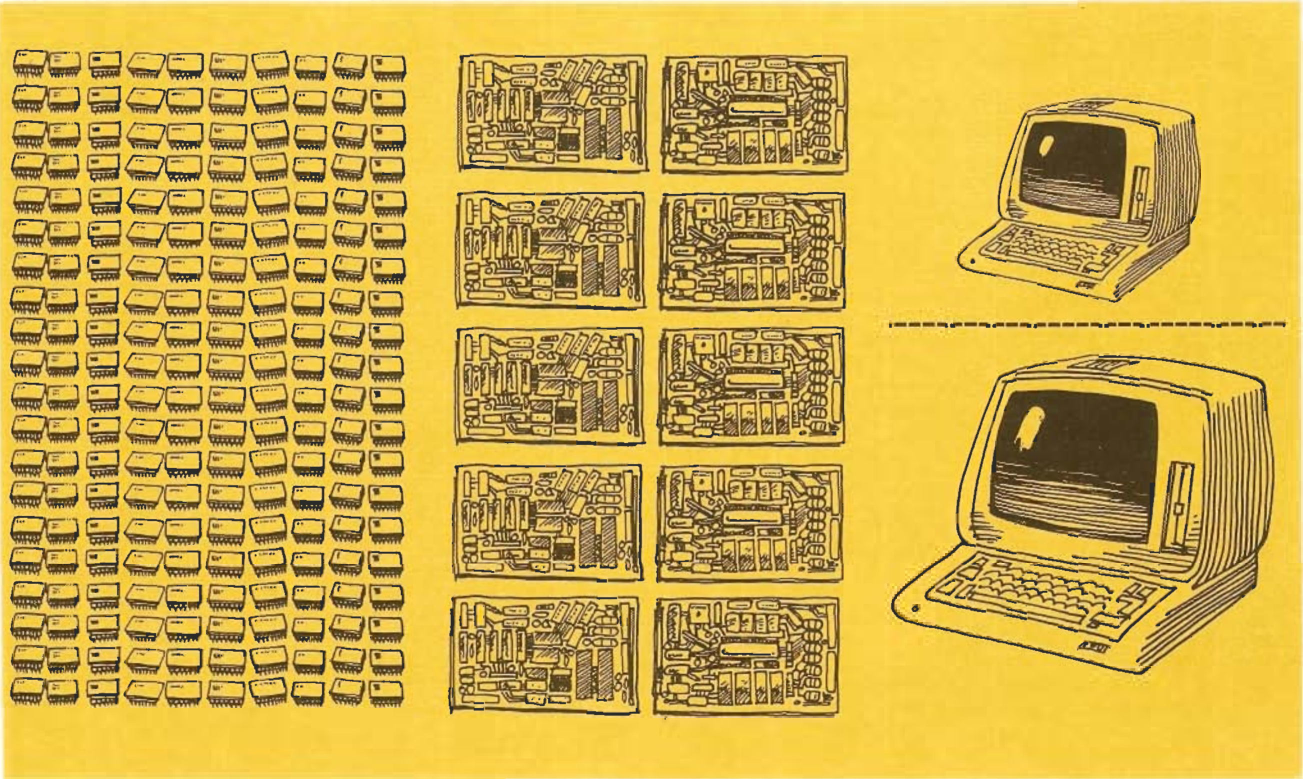


***Table 2.** How a respectable 0.5% device failure rate can become a 40% disaster. S. Russell of Teradyne has presented this mathematical probability, based on standard attitudes on acceptable quality levels and realistic failure rates caused by static discharge. He observed that if you allow static to degrade just 0.5% of the devices going through an assembly area and are installing 20 devices per board, the potential board failure rate is 10%. But with five boards per typical system, the likelihood of premature board failure reaches 40%.*

ture field failures. Reduction of service calls alone can make an organization more effective and more profitable. If necessary, custom static control field service kits can be produced to ensure that technicians can use the correct materials and procedures in their own workplace. In any case, the investment required to achieve this level of precaution is small when compared to the potential savings.

The end user link

Equipment users are spread throughout all segments of the commercial, industrial and consumer sectors. Governments, financial and insurance institutions, education, retailing, hotels and restaurants, general industry, and individual homeowners are all consumers and operators of a variety of sophisticated electronic equipment.

Although the equipment itself is diverse, all of it is sensitive enough to electrostatic damage to potentially cause breakdowns, interruptions and errors in everyday situations. Electronic typewriters, telexing and telecommunications equipment, word processing and all forms of computing equipment, electronic cash registers, numerical controls, security systems, graphic processors, electronic automotive systems—the list seems never-ending.

To complicate the issue, most users are unaware that they, as human beings, are the biggest generators of static electricity and that they personally present the greatest danger to microprocessor-driven equipment. Creating an understanding of this fact and instituting simple control procedures should be a high priority.

Attaining this goal is a long process, but it will only be reached by a co-operative effort. Just as the electronics industry understand the eventual benefits, the purchaser of a piece of equipment should be made aware of the problems with ESD, and benefits accruing from control procedures. Emphasis must be given to *prevention* of ESD problems, rather than *detection* once a problem occurs.

For example, if a fault occurs on a piece of electronic equipment the normal procedure would be to call a technician to solve the problem. Many are intermittent and thus difficult to identify. If the fault happened to obliterate an important piece of data, the cost associated with reworking the data, the lack of productivity due to equipment downtime, plus the service call itself can be determined with reasonably accuracy. This cost in a single instance can easily be equivalent to, or greater than, the cost associated with adequate electrostatic prevention.

Consumer education vital

Despite the acknowledged necessity of using static control procedures at the manufacturing level, a purchaser is rarely told that the equipment has ESD-sensitive components. Beyond question, damage can occur with operator handling when static control floor mats or conductive keyboard pads are not used. Static control measures are gaining some acceptance among these users, but a greater effort from all industry segments would provide benefits for all.

Static

For example, equipment manufacturers and their associated component suppliers would benefit through reduced warranty costs and gain a greater market acceptance for the reliability of their products.

Service companies would be able to make sure that field calls were for problems other than ESD-related. It is even possible that a reduced-cost service contract could be offered to customers using static control procedures.

The consumer would undoubtedly benefit because there would be less equipment downtime, and fewer errors introduced to the system. Productivity savings would accrue.

In summary, awareness of the potential damaging effects of electrostatic discharges or microelectronic components is widely accepted. Greatest acceptance has come from the manufacturing sector but some field service organizations, and a small number of equipment users are also familiar with static control precautions.

The static control system is only complete when all elements are in place and utilized. ESD precautions should include control of both conductive and non-conductive surfaces during all phases, from receiving and storage through assembly and shipping to field and end use.

Education of the end user remains a key facet in the reduction of ESD-realted problems and their associated costs. CEE

The hardware of static protection

Static has been around ever since the ancient Egyptians, (or was it the Romans and Greeks?), stroked their pet cats on cold days. It also reoccurred when the first transistorized car radios were introduced because the first cold, dry day saw the input RF amplifier blow its base-emitter junction a microsecond after the car key was inserted in the door!

Now there's anti-static spray for the cat and a voltage dependent resistor plus a dissipative base-emitter diode to protect the NPN, PNP or IC in the car. But the advent of statically fragile field effect semiconductors, EPROMs and CMOS to the large-volume production floor means that even the parts tote boxes, the factory floor and the shipping wrap and containers need to be Faraday-caged and static proofed. And so, enter the static hardware specialists, still, to some extent, charged (pun intended!) with the requirement to convince the end-users that static is here to kill.

Buckhorn boxes

Anti-static conductive boxes are the bread and butter of Buckhorn Materials Handling Products Inc., of Mississauga, ON. Buckhorn's Jim Morrison says that at least eight sizes of these containers are made in Canada. Formerly known as Nestier, the company has two ranges of containers which can be made from polyethylene as well as from a proprietary brand of carbon loaded non-conductive plastic. The two styles are a Modubox, with adjustable dividers, a flat area for labels and/or bar code placement and a reinforced lip for automatic extraction and edge racking. The other style is a conventional open front bin.

Buckhorn keeps some $60 000 of anti-static containers on hand: time for development and tooling for custom containers is five to six months, though the US and Canadian operations have many standard sizes available off-the-shelf.

Current sizes are from .01 to 8.2 cubic feet.

Shocking carpet

Once upon a time, it was common to hand your associate a fully charged 10 microfarad capacitor and watch the facial contortions when it discharged across the palm of the hand. Tom Rennie, marketing manager of Badische Canada, has a similar toy that he uses to show the static-dissipative properties of Badische's patented Zeftron® nylonfiber. Rennie has his own high-voltage generator, battery operated with a high frequency oscillator, rectifier and charge capacitor. Charged, he puts the base plate on the carpet. The well-conducting carpet material leaves no charge on his probe, but your average carpet material still allows plenty of sparks to fly from the undischarged capacitor.

However, there are a couple of points in this connection: there's the electro static problem of human comfort and convenience, and there's the ESD of a lower potential for human discomfort, but one that kills chips and generates computer lies: garbage out can result not only from garbage in, but also from static in.

The voltages involved in electrostatic discharge (ESD) are high. People are sensitive to ESD above the 3.5 kV level. ESD at above the 2 kV level can cause operating errors and even component damage in computers, especially advanced microcomputers. For that reason computers used in a general office environment require greater protection against ESD than is provided by standard anti-static carpet. Computer grade carpet uses highly conductive fibers and construction to prevent the development of high electrostatic potentials.

Carpet . . . and carpet

The carpet industry developed a number of techniques for reducing the amount of static generated. One early method, still in use, involves treating the carpet with moisturizing and lubricating agents. This gives some protection, but the treatment has to be renewed frequently, and it is not appropriate for high traffic areas. The treatment tends to encourage soiling, and can cause severe maintenance and appearance problems. Maintaining humidity levels at 40% or more can substantially reduce electrostatic generation, but is difficult to achieve in dry or cold climates.

A better solution appeared in the late 1960s with the incorporation of metallic fibres in the carpet pile. The first experimental fibres were soon replaced by some form of carbon-conductive filament, with vastly superior wear properties.

The conductive fibres are an integral part of the yarn system. In loop construction the conductive fibre runs along the entire length of the carpet; in cut pile construction it begins and ends in each tuft. Many cut pile carpets use a conductive primary backing which improves their ability to dissipate static.

Static-controlled carpets effectively solve comfort problems by holding ESD levels below 3.5 kV. Specifications for a computer-compatible carpet, however, require that static charges should be reduced to much lower levels, and that they should be dissipated quickly so that a person approaching from an unprotected area does not carry a dangerous charge to computer equipment. Meeting such specifications requires new attention to materials, to methods of construction, and to test procedures.

A *comfort* carpet takes about 10 seconds to bring the charge down to the 3 kV range, adequate for general use but inadequate in a computer environment. The *computer* carpet must bring the charge down to less than 2 kV in about 1 second, and keep it well below the danger level.

Tom Rennie says that Zeftron® nylon computer grade carpet is guaranteed not to generate more than 2 kV: minimum resistivity is 150,000 ohms per square, maximum resistivity 1×10^8 ohms per square.

Other low volts floors

Carpeting is not the only anti-static floor material. Some manufacturing environments find it not acceptable. Ford Electronic's new plant in Markham, ON uses white anti-static paint over the entire production area. If you are a car manufacturer, the thought of a carpeted assembly floor must be anethema! Mitel Corp. in Kanata, ON has, on the other hand, a 25,000 square yard research and development area entirely floored with specially developed computer grade carpet.

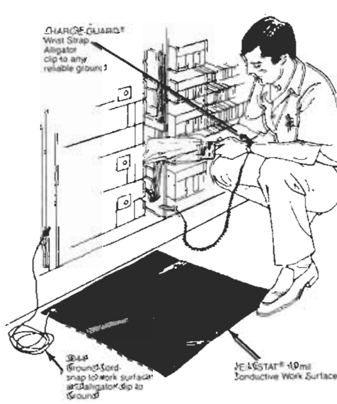
There's also conductive vinyl tile and conductive carpet squares available, but these have theoretical problems in charge transfer when used in any significantly large area.

The end choice may be the toss-up between apparent wear and appearance. A computer grade carpet, notes Tom Rennie, can have any color, feel and quality that an interior designer could ask for. He's also talked to the service manager of a computer manufacturer who believes that 60% of his service calls result from static.

Who knows—maybe CMOS green will become the institutional floor cover choice for computer banks! CEE

Static-safe field service procedure

1. On reaching the trouble location, the repair person should unfold and lay out the work surface on any convenient area such as table or floor adjacent to the trouble location.
2. Attach the ground cord to the "work surface" via the snap fasteners and attach other end of ground cord to a reliable ground via alligator clip. Water pipes, unpainted equipment frames, electrical conduit or building frame members usually comprise accessible and reliable ground locations.
3. Slip on a wrist band that is comfortable, but still contacts the complete circumference of the wrist. Contact between wrist and wrist band need not be tight, but extremely loose fits are not desirable. The wrist bands are often color coded; blue is the large size and camel is the small size for 3M products.
4. Snap ground cord to wrist band. Attach other end of ground cord to reliable ground via alligator clip. Since conductive work surface is volume conductive plastic, personnel may alligator clip the wrist strap to the plastic film provided it is properly grounded.
5. The repair person is now safe to remove and handle static-sensitive components. Once the suspected board is removed, it should be immediately placed in a static shielding bag. The replacement card can then be removed and inserted into the equipment frame. If a static shielding bag is not available, the trouble board may be wrapped in the work surface for delivery to the repair facility.
6. If the suspect board is to under go on-site testing or repair, it may be safely placed on the grounded work surface. Once grounded, the conductive film cannot hold static charge. The high conductivity of the material insures it will shield the board from static laden carpeting or vinyl floor tile.
7. If recalls persist and the possibility of user-caused static damage occurs, placement of a permanent static control floor mat in front of the troubled equipment may be required.



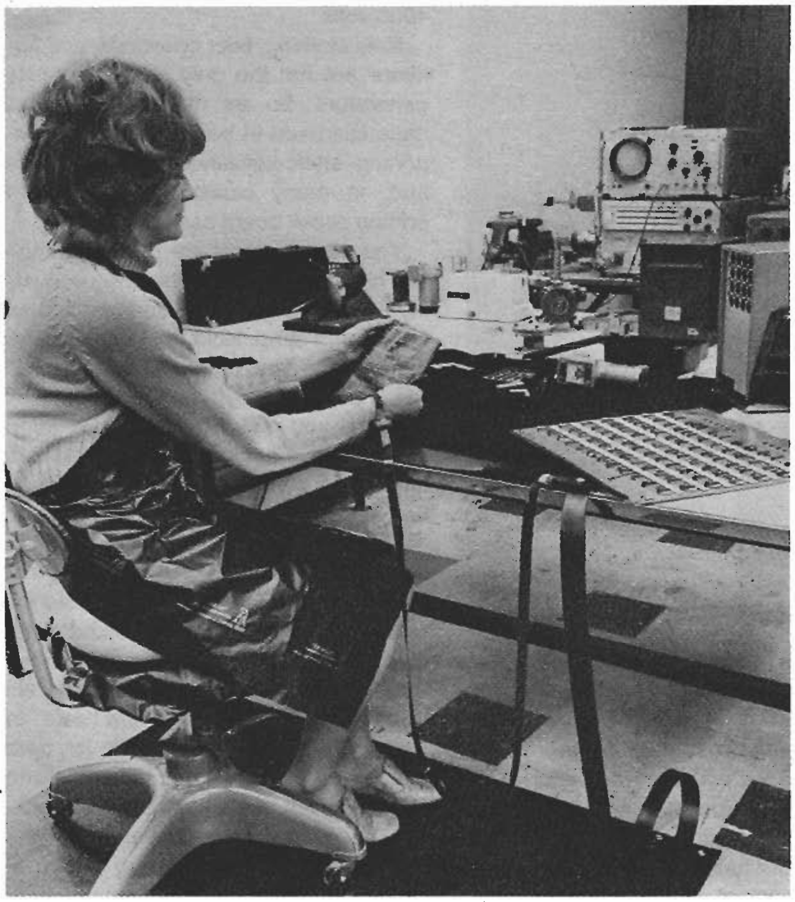


Photo courtesy 3M Co.

HOW TO HANDLE MOS DEVICES WITHOUT DESTROYING THEM

The life span of many MOS devices depends on what happens between the time of purchase and installation.

BY LESLIE SOLOMON, Technical Editor

MOS TECHNOLOGY has brought tremendous advances to modern electronics. However, MOS devices suffer from one fatal shortcoming: they can easily be destroyed by static electricity when they are handled or being installed in a circuit. Even so-called "protected" MOS devices are not immune from being ruined by static electricity if proper precautions are not taken.

In this article, we will discuss the physical makeup of the typical MOS device and see how and why the MOS device is so easily destroyed. Then we will detail some of the steps you can take to prevent destruction of the device.

MOS Device Construction. In a circuit, a MOS device "looks" like a voltage-controlled resistor in which the equivalent MOS resistance between the drain and source is varied by a *voltage* applied to the gate electrode. (See Fig. 1.) Physically, the gate electrode is a thin layer of metal deposited on a very thin (about 1000 Angstroms) layer of silicon dioxide (glass). This layer of glass effectively insulates the gate from the substrate, in essence, forming a capacitor whose plates are the gate and substrate and whose dielectric is the layer of SiO_2 between the gate and substrate.

The strength of the electrical field that can rupture the SiO_2 layer is about 100 volts, at which point, a "punchthrough" can occur (Fig. 2.) Such a punchthrough catastrophically destroys the MOS device permanently.

Most MOS devices have an input resistance on the order of 10^{14} ohms. Using this figure, it can be seen that a current of about 10^{-12} ampere (10 pA) can generate a 100-volt potential that can break through the layer of glass and destroy the device. Some semiconductor manufacturers protect their MOS devices with a variety of circuits, the built-in zener-diode-resistance method being the most common.

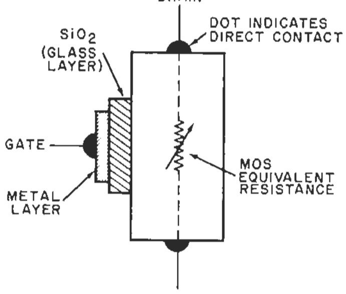


Fig. 1. Typical MOS device showing the insulated gate.

The schematic representation of a typical "protected" MOS device is shown in Fig. 3. Note the built-in zener diode that identifies this as a protected device. The "source," "gate," and "drain" electrodes are the equivalent of the "emitter," "base," and "collector" electrodes of the typical bipolar transistor. (The "substrate" lead of the device is usually connected to the source lead.)

In most cases, the zener diode that protects the MOS device conducts at about 50 volts. However, selection of the "substrate resistance" can present a problem. This resistance must be great enough to limit current flow to prevent destruction of the zener diode, but it must not be so high that the sum of the voltage drop across the zener-resistance combination exceeds the breakdown voltage of the SiO_2 layer. Manufacturers are making improvements in their protective schemes, but as of this writing, there is still no such thing as complete protection.

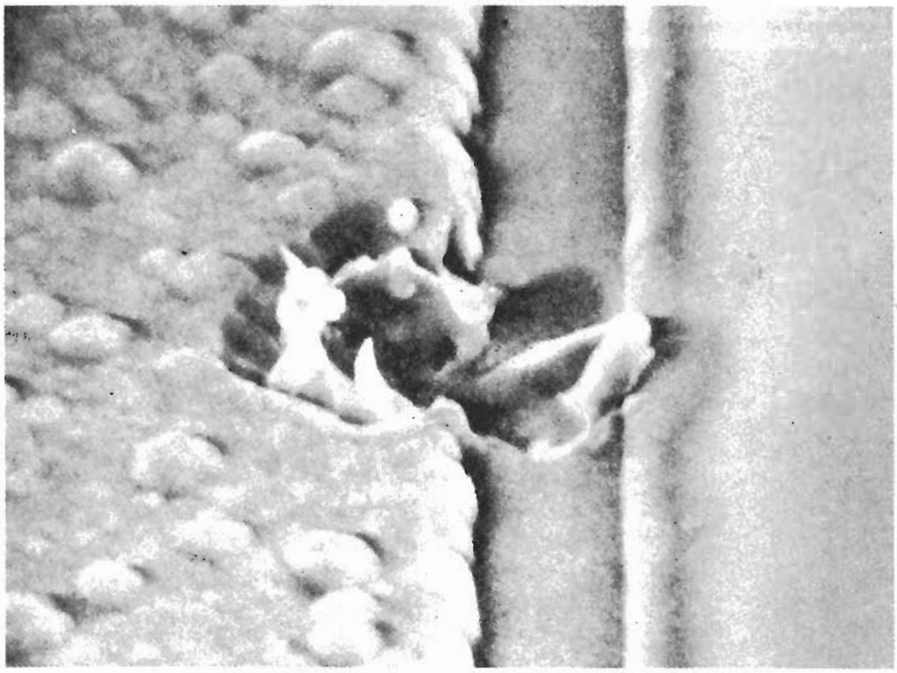


Fig. 2. Magnified (4300X) view of a cell-destroying punchthrough that has catastrophically destroyed the semiconductor device.

Static Charges. High-voltage static charges are generated whenever there is motion between certain types of materials. A partial listing of typical generators of this "triboelectricity" is given in the table.

ELECTROSTATIC CHARGE GENERATORS

Workbench Covering
- Any plastic (except conducting)
- Finished wood
- Most synthetics
- Ungrounded metal
- Glass

Floors
- Any plastic (except conducting)
- Waxed surfaces
- Most carpeting

Chairs
- Fiberglass
- Plastic (except conducting)
- Fabric covered
- Ungrounded metal
- Finished wood

Tools
- Plastic nonconductive solder suckers

Clothing
- Wool, silk, synthetics, furs

Packaging Materials
- Everything nonconducting

We are all familiar with the considerable spark that can be generated as we reach for a doorknob or light switch after walking across the carpeted floor. Walking on a carpeted floor, sliding into or out of a chair or car seat, or even brushing across the surface of a workbench or table can build up a high static potential. Even the seemingly innocent acts of combing our hair and opening the wrapper on a pack of cigarettes or candy can generate a tremendously high static potential.

To understand how this happens, you must visualize yourself as part of a capacitor. You are one plate of the capacitor, the insulating soles of your shoes are the dielectric, and the ground or floor is the other electrode. Typical human capacitance values can range from 80 to 140 pF. Because the spark generated when this "capacitor" is discharged is a function of the energy stored in the capacitor ($CV^2/2$), body capacitance plays an important role when it comes to handling MOS devices. Measurements have revealed that the electrostatic potential can reach between 2000 and 4000 volts.

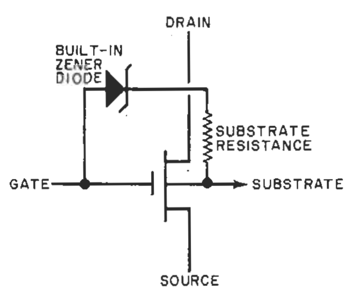


Fig. 3. The protection of a MOS device is usually 100 volts.

Note clothing, floor coverings, and furniture are not the only static-electricity generators. So are many of the usual materials used in packaging and transporting static-sensitive semiconductors and, in many cases, fully populated printed circuit board assemblies.

You can demonstrate the generation of a high static potential generator by using a simple desk tape dispenser and an NE-2 neon lamp. Hold the lamp close to the tape as you rapidly peel about 18" (45.7 cm) of tape from the roll. In dim lighting, you will note that the lamp flashes as the tape rapidly peels off. Now, drop the lamp into a polyethylene bag and rub the bag against a sweater in a darkened room. Again, the lamp will flash. Peel the tape off about an inch or so above a loaded ashtray and note the results. Keep in mind that it takes about 4kV to lift the ashes one inch.

One would expect that the tools we normally use in electronics are "safe" to use on MOS devices. This is far from true. One dangerous tool to use around MOS devices is the plastic solder sucker. The sudden rapid movement of the plastic piston in the housing sleeve of the sucker can generate a very high static potential. Another tool is the soldering iron. Unless it is grounded at the tip, the iron can be a dangerous static carrier.

After looking over the list given in the table, you may be wondering if there is *anything* you can do to assure safe handling and installation of MOS devices. Rest assured that there is and that we will be dealing with this particular subject later in this article.

The destruction of a MOS device results from the rapid discharge of static electricity across the elements within the device, usually with sufficient energy to rupture the SiO_2 layer. Carefully note that this is *not* the voltage to ground; it is the *potential difference* between the device's pins that does the damage. Eliminate the potential difference and you eliminate the damaging charge. Note also that no matter how high the static potential you build up by shuffling your feet on a dry carpet, you cannot "zap" one hand with the other—because there is no potential difference.

The problem with MOS devices occurs when the device's pins are placed between two points that have a high potential—usually static—difference. This is why many construction articles advise you to place one hand on the copper traces of the printed circuit board when

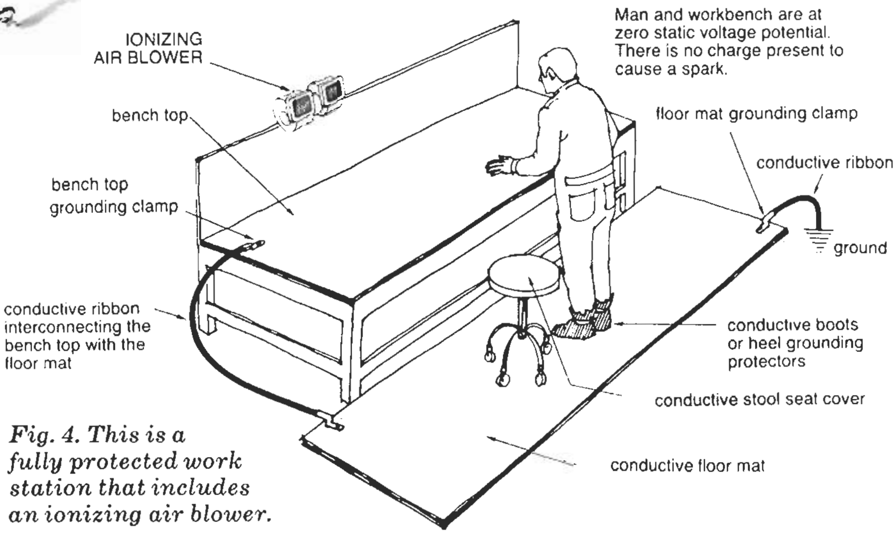


Fig. 4. This is a fully protected work station that includes an ionizing air blower. (Photo courtesy 3M Co.)

installing MOS IC's. This equalizes the potential difference. Such articles also tell you to handle the IC's only by their cases—*not* by their pins.

By touching the copper traces on the pc board when you install MOS devices in a circuit, you bridge conductors with a resistance that eliminates possible potential differences and discharges the human capacitor. It is even better to bridge pc board copper traces with a conductor that is better than human skin because skin resistance can be rather high in many cases.

Avoiding the Problem. If you plan to work with MOS devices, here are some things **YOU SHOULD NOT DO:**

- Insert MOS devices into any plastic containers or carriers unless they are of the conducting types.
- Place MOS devices or pc board assemblies on which they are installed in ordinary plastic bags.
- Hand a MOS device to another person who is not antistatic protected.
- Attempt to test a MOS device with a multimeter, even those with "low-power-ohms" functions.
- Wear nylon or other synthetic clothing. Wear clothing made from cotton or cotton blend fabrics.
- Remove jackets, sweaters, etc., near a MOS device. (Remember the experiment with the tape dispenser.)
- Handle MOS devices by their pins.
- Slide MOS devices across a surface.
- Handle Styrofoam or other plastic hot- or cold-drink cups, open cigarettes or candy packages with "cellophane" wrappers, or use plastic combs or any other item that is either plastic or wrapped in plastic.
- Use plastic solder suckers on or near the pins of MOS devices.
- One thing that most people never consider when working with MOS devices is the humidity of the working environment. The air in a very low-humidity environment is dry and has a very high resistance. Arid air will not discharge the static electricity as fast as moister air. Be particularly on your guard during the low-humidity winter months. Try to work in an environment where the relative humidity is between 30% and 50%.

Now here are some things you *should* do. MOS devices generally recommend that you wear some type of conductive wrist strap that is connected through a relatively high resistance to earth ground. This is usually followed with the instruction to similarly ground the tip of your soldering iron, tools, and test instruments that might come into contact with MOS devices both before and after they are installed in a circuit. If you heed these precautions and are working at a metal workbench or table, protect yourself from accidental shock (the protection of the MOS device is secondary here). *Never* connect your metal work station directly to ground; there should always be a minimum of 200,000 ohms between your skin and actual ground in case a faulty appliance power line or chassis has leakage to ground in excess of 0.5 mA.

Although the above precautions are one way in which you can protect your MOS devices from being zapped, it is important that you bear in mind that it is not the potential to ground that presents the hazard to the devices but the voltage *difference* that is the culprit. Therefore, all that must be done is to find some way to equalize the possible potential imbalance and thus eliminate the hazard.

Fortunately, there is another solution to the problem. This involves the use of antistatic (conductive) plastics. The RC-AS1200 conductive "pink" plastic from Richmond Division of Pak-Well and "Kimcel" from Kimberly-Clark are impregnated with a special noncorrosive organic antistatic liquid that migrates to all surfaces of the material. "Velostat" from 3M Company is a conductive plastic that has a medium resistance per square inch. Of course, we are all familiar with the black conductive plastic

GROUNDING AND SHOCK HAZARD

Faulty electronic equipment that is not properly grounded can kill! This is the reason most modern electrically powered appliances and equipment are fitted with three-conductor power cords. One pair of conductors in the cord supplies the actual working power from the ac outlet, while the third conductor (usually color-coded green) should be connected between the metal chassis of the appliance or equipment and a good earth ground.

When installing IC's and other components in a circuit, many professionals recommend that you connect your body and the tip of your soldering iron to earth ground through a minimum resistance of 200,000 ohms. The resistor value is selected so that, in the event of an accidental short circuit, the current flow that does the actual damage is limited to 0.2 mA or less, which is considered to be a safe level. A current flow of this magnitude can barely be discerned. Listed below are the effects of electrical current passing through the body from arm to arm. The measurements were made at 60 Hz.

Current	Effect
0 to 0.5 mA	Little or no sensation
0.5 to 1 mA	Tingling sensation
1 to 5 mA	Mild pain
5 to 10 mA	Severe pain
Over 10 mA	Muscles contract
100 mA to 2 A	Ventricular fibrillation; lethal
Over 2 A	Lethal if sustained; momentary contact produces burns and physiological shock but good chance of recovery.

The above currents and effects are for a typical human being in good health. Except for the last, all effects given are for sustained contact with the current.

foam blocks used as carriers for MOS devices during shipping.

These antistatic plastics, with the exception of the last item, come in all forms—from film bags to heavy sheets to semirigid tubing. They can be used in sheet form for workbench tops, as a floor mat around the work station, and with a wrist strap and soldering-iron attachment.

The antistatic bags can be used to store static-sensitive semiconductors. You should have some distinctly labelled antistatic bags for storing semiconductors and completed MOS board assemblies.

Protected Workbench. A typical commercial work station that is fully protected is shown in the lead photo. Here, the technician is wearing a conductive plastic apron, is sitting on a conductive seat cover, and has her feet on a conductive floor mat. The top of the workbench is covered with a sheet of conductive plastic, and a conductive-plastic strap is attached to her bare wrist. A somewhat similarly protected work station is shown in Fig. 4. Here, the station is equipped with an optional ionizing air blower. In both cases, the entire work area, including the technicians, are at the same potential. And since there are no voltage differences, there can be no damaging static discharges that can destroy MOS devices.

If you wish to protect your work station as described here, you can obtain conductive plastic by contacting your local representative of 3M Nuclear Products (3M Center, St. Paul, MN 55101); Richmond Division of Pak-Well (P.O. Box 1129, Redlands, CA 92373); or Kimberly-Clark Corp. (Interior Packaging Dept., Neenah, WI 54956). As an aid to POPULAR ELECTRONICS readers, a hobby workbench setup consisting of a 20" × 12" (50 × 30 cm) Velostat working surface, wrist band with connecting strap, and an assortment of antistatic storage bags (including some large enough to accommodate large hobby-type computer boards) is available for $14.95 from Associated Electronics, 1885 W. Commonwealth, Unit G, Fullerton, CA 92663.

In Conclusion. Though MOS devices are very sensitive to destructive discharges, you can take positive steps to greatly reduce or completely eliminate the problem at its source. By thoroughly protecting your workstation against static hazards, you can work in complete safety with any MOS device. ◇

The magic of static

By Michel Fontaine, Bystat Inc.

ESD will happen at every level of manufacturing, from the wafer fabrication to the user. The problem requires industry wide attention and the establishment of industry standards.

This reflects significant losses by several major firms in the electronic industries. These damages will have different configurations. The most common are:

- Intermittent or transient failure (ghost bite, malfunction)
- Breakdown—usually happens after direct contact of the IC with a high voltage static charge
- Latent failure occuring via degradation of the devices over a period of time. This suggests that a device subjected to repeated exposure to static charges less than that which could cause a direct failure for cumulative damage.

Yes, static electricity is expensive, if you do nothing . . .

There is no doubt that the more advanced your product in its production cycle, the more expensive it becomes to have ESD related failures.

Now that we know that it's happening, how do we justify the investment to the management? The only way to be sure is to determine your cost for a certain period of time (rework, field service and reject) and to compare the same test 6 months after the program is implemented; 6 months should be a minimum, you should allow more if you start a ESD program from scratch.

Next are resumês of case histories of different companies who performed the before and after calculations.

Case History I: Computer manufacturer

This particular company isolated one department and used it as a "static lab." Their justification for instituting an improved ESD protection program was based on actual ECL integrated circuit failures due to ESD induced electrical overstress. Although other device families have been noted to display similar failure mechanisms in the past, they were not included in the study, neither were problems experienced at computer installations relative to magnetic tape problems, and frame discharges causing noise interrupts also were not addressed.

After establishing the importance of ESD, they conducted a first general survey. The following are some of the most significant findings:

- Generally, no protection system was utilized by personnel handling components or assemblies eg. no wrist straps were used.
- Non-conductive static generating materials were commonly used in the work centres.
- Static protected work stations were few in number and most of them were not properly installed and maintained.
- Assembly protection was given only to MOS memory assemblies, and even there, some failures occured.

The failure mechanism was discovered in a variety of device types and in a large quantity of part numbers. All areas were reporting incidents of ESD failures.

- The cost factors showed that as the product moved through the manufacturing cycle, the failure cost increased exponentially; this generally agrees with industry observations.

Product selection

A special task force was put together to develop the ESD protection program. All manufacturing divisions were directed to implement this program within the guidelines of the specification developed. Wherever possible, static protective materials would be purchased through coordinated procurement efforts to gain the best cost advantage. The following products were selected.

A) Grounded wrist straps
B) Conductive table tops
C) Static protective bags
D) Topical anti-stat treatment
E) Static protective smocks
F) Conductive tile

Anti-static and Chemicals-in-electronics

This supplement to the CEE November 1985 issue is a file-for-reference section, conceived as a file for these two important, but not generally widely known about areas in electronics.

There's data on the hidden problems of electrostatic breakdowns; data on chemicals relating to printed circuit board manufacture, and on chemicals relating to manufactured items. Most of the significant companies, in Canada, in these areas, have contributed to this supplement.

If you're a buyer, specifier, end-user or an engineer in any electronics production or service facility, you will find this insert a valuable reference source. CEE

Show Guide Advertisers' Index

Result Summary

The ESD protection program has been in place for approximately two years. A constant upgrading of the system is still underway. Prior to the implementation of this program, the overall percent defective in the 10K ECL family was measured at .134% defective. The data base from which this information was obtained was over the total usage of this device family measured at the system test level.

A measurement was made again after basic ESD controls were put in place. The recent data over this period of time is placed at .055% or an improvement of .079%. This shows a reduction of 58% of 10K ECL defect. It has been observed that a significant amount of this failure reduction is due to the absence of ESD damage. Several devices actually show an increase in percent defective. Investigation into this failure showed factors other than ESD to be responsible for the failures.

Case History II: Defence contractor

A review of all EOS failures on a manufacturing line (covering a four year period) was conducted using failure analysis techniques. MOS Op Amps and C-MOS NAND gates were selected to evaluate the magnitude of the ESD problem.

As the severity of the ESD related failure became apparent and the costs were tabulated it was realized that this company was facing costs approaching $2 million per year. Their conclusion was that if the ESD control program was not implemented, continuing operating costs would become prohibitive.

When this manufacturer calculated the ESD failure cost, unexpected items were included, some of which were paperwork associated with research, laboratory and technical reports, manhours incurred by corrective action, failure diagnosis, the actual removal of the failed device, the cost of the failed part and overhead cost related to such activities.

The total cost of the above in 1979 was $4,500 per failure. In 1979 they incurred 68 failures plus 332 additional failures due to ESD. This yielded a total failure costs of $1,800,000 in 1979. These amounts reflect the manufacturers estimated failure cost given their involvement in highly sophisticated programs.

The following costs reflect the basic investment in their ESD program.

Bench top materials	$48,000
Tote boxes	$21,000
Wrist/heel straps	$4,000
Conductive flooring	$100,000
Guide-line documentation	$2,000
ESD awareness training	$2,400
ESD audit procedure	$5,000
Ionized air blowers	$2,700
Total:	**$185,000**

To this total an operating upkeep cost was calculated based on replacement cost of damaged wrist straps, table mats and ionizers. New manufacturing and product assurance personnel were required to take improved ESD awareness training. The cost of yearly ESD procedure failures (after they were implemented) were added to the total.

Upkeep of wrist/foot strap, etc.	$20,000
Training course (2 hrs x 100)	$4,000
Auditing	$5,000
Residual of ESD failures	$16,000
Total:	**$45,000**

ESD cost avoidance saving: $1.8 million, less $230,000, or $1.57 million.

When this problem was presented to management, the most important topic was cost saving. This is where the corporate pocketbook obtains the benefits. The avoidance cost saving includes the upkeep maintenance costs.

If you consider that every dollar sales increase will give you profit, and every dollar saved in cost will give you 52¢ profit, on the first year this company had a 872% return on their investment. CEE

Static control is a quality process

By Peter Green,
Market Supervisor, Electronics and Static Control,
3M Canada Inc.

Lightning never strikes twice in the same spot? Not so, according to the experience of the electronics industry, where it is well known that static damage can occur many times in a manufacturing environment.

Static discharges are random and insidious, being not always easy to detect. As a result, industries have taken the approach that prevention is better than cure, have a more reliable, higher quality product than they produced previously. Using good static control materials and educating employees in their use has allowed these companies to take significant strides in improving their products quality. On the other hand, failure to recognize and implement similar procedures could result in lack of competitiveness and subsequent failure in the marketplace.

The business of quality

Nowhere is there a business and industry sector that prides itself on being more forward-thinking and technologically advanced than the electronics industry in Canada, and quality is a major consideration. The philosophies of Crosbie and Juran are becoming corporate policy in companies like 3M, Burroughs, Motorola, ITT and others, and best-selling books and video tapes on the subject of quality improvement abound. Static control is a natural complement to this quality emphasis, and it should become as much a way of handling sensitive electronic components as quality improvement is becoming a way of life.

The basics of electrostatic discharge (ESD) are simple. Three forms of static charges exists. Triboelectric charges are derived from contact or separation of materials, commonly known as frictional charges. Damage can also be caused by inducing a voltage field from a charged object, or by direct discharge when contact is made between charged and uncharged objects.

The basics of all static control procedures are equally simple: handle all static sensitive components in static-safe guarded work areas; transport all static sensitive components in static shielding containers or carriers, and ensure that all suppliers of static sensitive components use static shielding packaging and shipping. It is not enough, however, to simply purchase conductive or anti-static materials and then expect the production or service departments to conform to adequate ESD requirements. The variety and capabilities of available materials is ever-expanding. Compatibility of one material with another must be a consideration.

To carry out an effective program, everyone involved must know what the materials are for, and someone should be assigned the responsibility of ensuring implementation and proper use. A parallel program to test static control products and measure their effectiveness in providing static prevention also is necessary. Without education and evaluation, how do you know you have an adequate static control process? Or, do you just hope you have?

Using the example of the "Quality Improvement" process, it may be seen that more and more inspection will not improve product performance. Rather, it will only add what are called appraisal costs, *(see table)*. It is far more realistic, then, to improve product performance and reliability (thus price/value to the customer) by using a preventative approach. Holding down the cost of bad product by stopping errors and faults from occuring is the reality of the prevention technique, *(see table)*.

Once it has been decided that doing things right the first time will produce maximum benefits for the company, it becomes quite obvious that ESD precautions are part of this process. Management must approve and demonstrate a solid committment to the procedures and policies that will allow an adequate preventative static control system to be put in place.

Tools and knowledge to do the job properly are critical. Equipment and materials must be capable of working together in a cohesive manner. An understanding of the 'why' and 'how' must be learned by everyone involved so the procedures become natural. Systems and materials must be tested regularly to ensure they still provide adequate static protection, and responsibilities should be assigned to allow monitoring of the system.

Finally, all departments of a company must be involved. From shipping and receiving, throughout assembly to field service, all must be part of the static control, and thus the quality improvement, process.

Interdependence a reality

Any company or person cannot be expected to achieve this by themselves. It is probably not an overstatement to say that no one company or individual knows all there is to know about either static control systems, manufacturing techniques, field service problems or a host of other areas of expertise that impact this process. There are, however, many experts who specialize in these fields.

As already stated, ongoing education and evaluation is important and necessary. In the electronics industry, technology is advancing daily. Very soon, for example, semiconductor manufacturers will be producing complex devices in large numbers that are based on gallium arsenide technology. It is already known that these circuits will be far more sensitive to ESD than current silicon-based components.

And, in fact, the development and production of static control materials and procedures to handle far smaller levels of static electricity are underway now to ensure that adequate capability exists to handle these new micro electronic products.

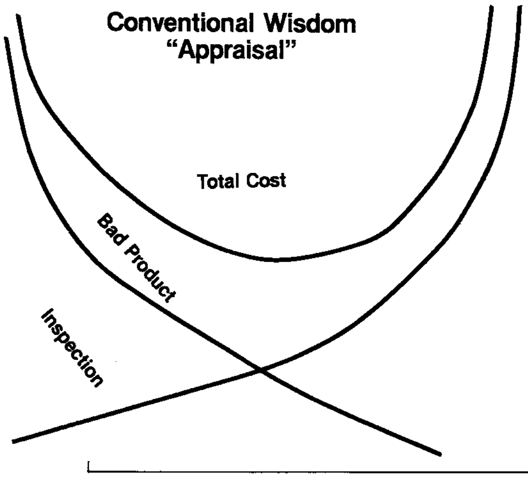
Re-auditing production assembly areas and field service requirements are a very important part of an ESD process. This is best handled by a competent analyst that understands the products and processes involved. If your company is large enough to warrant a full-time ESD co-ordinator, then that person may wish to consult with a representative of the manufacturer of the static control materials used.

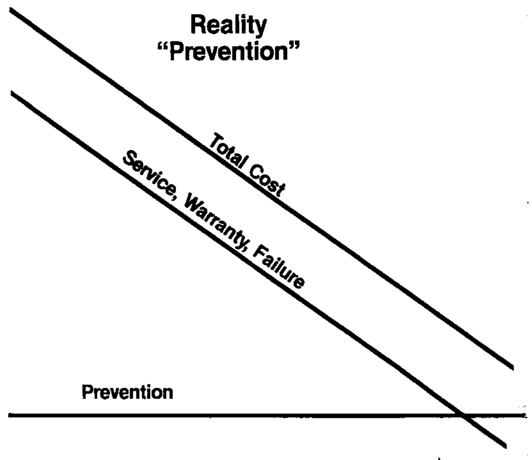
A significant portion of the electronic industry in Canada is made up of companies who are not manufacturers, but do service and repair the equipment they sell. Still others are members of the independent service industry. In both cases, the same criteria for handling circuit boards and their static sensitive components applies—with the same end results if safeguards are not applied. In this regard, the fact that people in this segment of the industry are closer to the end user market makes them more sensitive to the costs involved in not doing things right the first time. Employing preventative measures for service and repair is normal procedure. If ESD precautions are added to this process, the net result is a more productive and profitable organization.

Quality is forever

The 3M Company has implemented a quality improvement process globally. Many others employ similar methods throughout their organizations. The emphasis is defect prevention oriented—rather than defect detection oriented. Just as attention to and understanding the need for static control procedure in electronic servicing and assembly environments are essential, so the committment to improving the quality of the workplace and the environment is an ongoing process.

A competent ESD safeguard system must not become a program, for programs have a beginning and an end. It must become a process that needs monitoring, measuring, reauditing, revising and most especially, utilizing to it's complete extent. Static control procedures are an integral part of a process that will contribute to worker productivity, product improvement and reliability. CEE





Static Electricity Threatens

Starters and maintainers in a static control program

By Peter Davidson, Arbell Inc.

Any program that is to be effective must begin at the incoming inspection of components right through the manufacturing and final assembly processes to field service. Again, the complete appreciation of ESD and its effects makes this overall program mandatory especially in today's marketplace of extremely sensitive semiconductors.

It is impossible to eliminate all generators of electrostatic charge. Control, therefore, is necessary. The first step of any control program should be a survey with an electrostatic locating meter such as the ACL 300. Floors, personnel, equipment, tote boxes, etc. should all be monitored to determine the main sources. Once this is done the ESD control program can begin. This could include the use of the topical antistats, conductive acrylic floor waxes, conductive mats and tiles, static dissipative worksurfaces, conductive toteboxes, and ionizers. Two products which should be given careful consideration as part of the program are topical antistats and conductive acrylic floor waxes.

Topical antistats

Although for some time no one truly understood their functions, their potential contamination, or how long they would last in a given application, Topicals have evolved and grown to very sophisticated levels of functions and performance. Topical Antistats are generally liquids which when applied to a surface or material renders it static controlled. They usually consist of two basic components one being the carrier (solvent, water, alcohol, or other

solvents) and the antistat mechanism.

Overall, topicals are designed to minimize charging and dissipate a generated charge before it becomes a destructive or objectional factor. They normally function in three ways in order to provide maximum performance. First they reduce material coefficient of friction; second, they increase surface conductivity; and third, they interact with environmental factors to dissipate generated charges.

One such Topical manufactured by ACL Inc. is Staticide. This product which has been internationally approved can effectively eliminate all static buildup on the surfaces treated. Ease of application and the longevity of each application make this Topical a very practical and economic one as part of the ESD control program. Even more important however is the fact that the Staticide mechanism is effective in an environment with less than 15% relative humidity.

Conductive acrylic floor waxes

These are faily new on the market and function in a similar manner to Topical Antistats. The biggest difference however is that the mechanism is either in solution with the floor wax or in some cases chemically bonded to the wax. The use of conductive waxes will increase the wear life of the areas treated per application without loss of conductivity.

One such product is the new ACL Staticide Acrylic. ACL has developed a unique formulation of cross-linked conductive chains which provide high performance static control. The only way the treated surface will ever become non conductive is by physically removing the Staticide Acrylic.

Many ESD committees have concluded that products such as conductive floor tiles, conductive mats, conductive chairs, etc. must be used to combat their ESD problems. However, these products can take some time before final installation. Therefore, topical antistats are originally used for the interim period. The interesting fact however is that the results of using topical antistats is so impressive that they become part of the overall control program and in some cases some of the above mentioned products are never used.

High performance topical antistats can readily perform on any material against the toughest electrostatic decay standards. They are inexpensive, easy to use and safe for personnel and the environment. Before purchasing any conductive products it is suggested that topical antistats be used. CEE

A supplier recommends

An organization that has several years in the static control market describes policies for implementation that stand the tests of efficacy and time

The first and foremost step in any static control program must be a complete and sincere commitment from senior management. There is not much sense in proceeding with a static control program if management is not convinced of the dangers of static damage and if management is not prepared to authorize the appropriate capital expenditure. Obtaining the commitment from senior management may be easier said than done, it usually requires at the very least a general awareness program to educate the appropriate people. In addition it usually requires providing proof that static is indeed the cause of existing failures, which requires some exacting work.

Program implementation

Once the company is committed to implementing a static program it is quite important that someone within the organization has the responsibility of spearheading the entire program. Depending upon the size of this organization, it could be an individual, or a group of individuals. The responsibility must be clearly defined and must have teeth. The terms of reference must state the objectives of the static control program to be put in place; how the program is going to be defined and how the program is going to be evaluated. By having one individual or a team of individuals responsible the entire organization will be working together. At this point we have a commitment from management and we have one individual or a team of individuals with a detailed mandate. The next step is to identify the static control products and equipment needed for the program.

In order to do this we suggest that the first step is to analyze the type of devices being used and the location where they are being used. All integrated circuits are not susceptable to the same levels of electrostatic discharge. Some devices are much more susceptable than others and this fact can have a significant impact on the methods to protect from static damage. It is also important to assess how the sensitive components are being handled, for example are the integrated circuits being handled only in protective containers, or are they being handled by the human hand? Are the sensitive components being handled at the component level or the printed circuit board level or as individual devices. This information is very pertinent as to the types of static control measures to be taken.

Analyze environment

It is also necessary to analyze the existing environment within the various areas of the company. For example, the humidity level has a very significant impact on the levels of electrostatic discharge and a measurement of static fields in the plant may reveal low electrostatic field strengths when the humidity levels are high. Often humidity levels are high at a certain season of the year. It is probable that if the same humidity measurements are made six months later, for example during the middle of the winter when the humidity levels are low, then static field strengths will be multiples higher. An important factor in a plant is the number of operators and whether they are stationary or mobile also the number of work stations in use. All of these items are important environmental considerations for the needs of static control products.

Records . . . records!

It is quite possible that a company will have a partial static control program in place and clearly this must be taken into consideration. It is recommended that during this identification phase the rejection rates for all pertinent areas are recorded. This will provide a starting point from which the static control program once implemented can be evaluated. It is important to survey with a good field scanner the strength of static fields at stations where sensitive components are being handled, this will help determine what level of protection is required. At the conclusion of such a complete survey the following important information should be available; types of devices being used in different areas, identification of the existing environment of the company, the rejection rates in the appropriate areas and the levels of static field strengths in those areas. It will now be possible to define the products required. The approximate cost to procure those products can now be estimated and the education and training needed to bring the entire program up to steam can commence.

Involve your supplier

At this point some companies select a team of individuals to implement the static control program. We highly agree with this approach as there is usually no better person to educate and train the operators than the direct supervisor of a particular area. If the identification of the needs have been done in a complete and thorough manner the installation of the system should be a relatively straight forward procedure. However, this does not diminish its importance. A static control program is only as good as its weakest link and static control products will only work if they are used effectively.

We recommend that companies utilize the expertise of their suppliers when installing the static control products. We also recommend involvement of all the users of the static control products within the company.

Maintenance

All products in use have a life span and can eventually break down. A malfunctioning wrist strap, a torn static bag, or dirty dissipative table top material can all defeat the purpose of implementing a good program. The problem here is that the people involved may be suffering from a false sense of security, as they may not know the products they are using are not working correctly and that static damage will occur. All static control products must be maintained and tested on a regular basis. All first class static control programs have a written procedure for auditing, testing and maintaining the products in use.

The bottom line

These recommendations are intended as a guide for companies that are going to put in a sound static control system. There are obviously many approaches to controlling electrostatic discharge and this is just one approach. It is an approach however, that we have noted to be effective at many plant facilities and an approach which we feel is cost effective and static control effective. We cannot stress more strongly than to say that a good system is only as good as its weakest link. Many is the time we have seen a good system in place in the production areas, and in the test areas but nothing in place in the receiving areas and the shipping area.

A final thought can be, what is the cost of doing nothing! CEE

Conductive containers protect from static

Containers are a must for the protection from ESD of product in transit or storage. The plastic is conductive; and the specific material can affect performance.

By J.R. (Jim) Butler,
General Manager,
Buckhorn Material Handling

Static protective boxes are much in evidence here

Electronic component manufacturers and assemblers are increasingly using conductive plastic containers to reduce the destructive effects of electrostatic discharge on sensitive parts. Conductive containers help protect the contents from hidden damage and component degradation by static electricity. Conductive containers are also being used for shipping and storage containers for finished electronic products.

Static electricity is the enemy

Static charges are generated in most material that moves and can become very large in nonconductive materials, since there is no way for the charges to dissipate. When objects that have different charges come within close proximity, electrical current passes between (and through) them.

Without protective measures, ordinary handling of parts often produces static potentials of thousands of volts (even though the small currents are not usually felt). Some metal oxide semiconductor components can be destroyed or degraded by the discharge of as little as 50 volts. As higher-density integrated circuits are developed, the risk of ESD damage increases due to the decreasing size of semiconductor junctions. Even finished products, particularly portable, battery-operated devices, such as calculators, computers and gauges, can be subject to ESD damage.

Containers made of untreated plastics have been recognized as a source of many production and quality control problems in the electronics industry. However, plastics can be impregnated with a conductive material, such as carbon, as to allow a clear path to ground charges, allowing them to leak off harmlessly. Unlike metal, such conductive plastic won't arc or short out electrical devices contacted accidentally, but will dissipate a static charge fast enough to protect sensitive MOS components.

Antistatic fluids can also be applied to plastics to allow surface charges to spread and diffuse, providing some protection in certain applications. But for material handling in production environments, impregnated conductive materials offer better protection by shielding against induced static fields, dissipating surface charges throughout the material, not just across the surface and retaining their conductive integrity in spite of repeated handling and use.

The amount of conductivity can vary from product to product. According to Ray Gargarella of Buckhorn those sold as "antistatic" have a surface resistivity of about 10^{11} ohms per square while the "conductive" may be as low as 10^3 ohms per square. Buckhorn makes tote boxes, bins and other containers by an injection moulding process from two different formulations, each with a different conductivity level and different measurements of protection.

Others in the field consider surface resistivity values of less than 10^5 ohms per square (antistatic) to be dangerous, since the rate of discharge may induce secondary charges in nearby components.

continued on page S14

Static electricity—the causes

A summary of the basics, and definitions for static electricity

By Michel Fontaine,
Bystat Protection Inc.

Static-Electricity is a stationary electrical charge. Non-conductive and ungrounded conductive materials have the ability to take on, and hold, a stationary electrical charge or potential. Some common materials acquire a charge of several thousand volts in normal handling.

How do materials become charged?

Materials acquire a charge in one of two basic ways, although there are many different methods to accomplish these:

1. Contact and separation of two surfaces provides an interchange of electrons from one surface to the other, leaving one surface positively charged and the other negatively charged. This is called the triboelectric effect.
2. A charged material has an electromagnetic field surrounding it. A conductive material being exposed to this field can acquire a charge. This is called polarization.

What makes a material charged?

One of two methods above will cause a material to have either an abundance, or deficiency of electrons. This results in the material being electrically unbalanced, thereby having either a positive (deficiency of electrons) or negative (abundance of electrons) charge.

If the charge is stationary, how can it cause an effect?

Although the charge is stationary it can effect objects in the following ways:

1. If a charged material comes near, or in contact with, another which had the capacitance to accept or donate electrons, an instantaneous flow of electrons will result. This flow is called a discharge and usually takes the form of a spark.
2. A charged material or object has a stationary electromagnetic field

continued from page S12

Ray says "an electrical current always generates a field around it" When considering the right container, it's a trade off between getting rid of the charge as quickly as possible (anti-static) or avoiding secondary charges, that could create other damage (conductive.)

All conductive containers are not alike

Selecting a container for your particular application requires a great deal of care. Design and materials must be considered if you are to get the product you need and the flexibility of the container must be kept in mind, due to the fast changing needs of the electronics industry.

According to Jim Morrison, Buckhorn containers are made of a material having a surface resistivity of 10^3 to 10^5 ohms/per square as tested under ASTM D-257 making the container more than suitable for electrostatic dissipation. The flexible design of the container line, offers unlimited modular capabilities for present and future requirements. CEE surrounding it. A conductor moving through this field, or the field through it, induces an electric current to flow through the conductor. This is called electromagnetic induction.

3. As stated earlier, a conductive material in the presence of an electromagnetic field can acquire a charge. This is called polarization.

4. When a nearby charged material, or object, is discharged, the resulting spark emits a traveling electromagnetic field, which can cause the effect described in items 2 & 3 above. This is called RF Voltage.

What damage can static cause?

While there are many types of damages caused by static, they can be grouped in three categories:

1. Destruction: High voltages and instantaneous flow result in the melting of metallic oxides, and other components.

2. Life degradation: Unplanned current flow not sufficient for destruction can cause early device failure. A portion of the area called infant mortality might very well be none other than static damage.

3. Inaccurate operation: Transient induced currents, and polarization, can affect the design parameters of a device causing it to function in an unplanned sequence, or not within design tolerances.

Definitions

Anti-static material ESD protective material having a surface resistivity greater than 10^9 but not greater than 10^{14} ohms per square.

Conductive material ESD protective material having a surface resistivity of 10^5 ohms per square maximum.

Decay time The time for a static charge to be reduced to a given percent of the charge's peak voltage.

Electrical and electronic part A part such as a microcircuit, discrete semiconductor, resistor, capacitor, thick or thin film.

Electrostatic discharge (ESD) A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

ESD protective material Material capable of one or more of the following: limiting the generation of static electricity, rapidly dissipating electrostatic charges over its surface or volume, or providing shield from ESD spark discharge or electrostatic fields. ESD protective materials are classified in accordance with their surface resistivity (or alternate conductivity) as conductive, static dissipative or anti-static.

ESD sensitive (ESDS) items Electrical and electronic parts, assemblies and equipment that are sensitive to ESD voltages of 15,000 volts or less as determined by the test circuit of figure 1. ESDS items are classified as:

A. Class 1: Those sensitive to voltages of 1,000 volts or less;

B. Class 2: Those sensitive to voltages greater than 1,000 volts but less than or equal to 4,000 volts;

C. Class 3: Those sensitive to voltages greater than 4,000 volts but less than or equal to 15,000 volts.

Electrostatic field A voltage gradient between an electrostatically charged surface and another surface of a different electrostatic potential.

Ground A mass such as earth, a ship or vehicle hull, capable of supplying or accepting large electrical charge.

Hard ground A connection to ground either directly or through a low impedance.

Insulative material Material having surface resistivities greater than 10^{14} ohms per square.

Protected area An area which is constructed and equipped with the necessary ESD protective materials and equipment to limit ESD voltage below the sensitivity level of ESDS item handled therein.

Protective handling Handling of ESDS items in a manner to prevent damage from ESD.

Soft ground A connection to ground through an impedance sufficiently high to limit current flow to safe levels for personnel (normally 5 milliamperes). Impedance needed for a soft ground is dependent upon the voltage levels which could be contacted by personnel near the ground.

Static dissipative materials ESD protective materials having surface resistivities greater than 10^5 but not greater than 10^9 ohms per square.

Surface resistivity (Ps) The surface resistivity is an inverse measure of the conductivity of a material and equal to the ratio of the potential gradient to the current per unit width of the surface, where the potential gradient is measured in the direction of current flow in the material. In another words it is the resistance to electricity to flow on the surface of the material.

Note Surface resistivity of a material is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial. Surface and volume conductive materials and has the value of ohms per square.

Volume resistivity (Ps) The volume resistivity is an inverse measure of the conductivity of a material and is equal to the ratio of the potential gradient to the current density, where the potential gradient is measured in the direction of current flow in the material. It is the resistance to electricity to flow through the material.

Note In the metric system, volume resistivity of an electrical inculating material in ohm-cm is numerically equal to the volume resistance in ohms between opposite faces of a 1cm cube of the material. Volume resistivity in ohms/m has a value of 0.01 the value in ohms/cm. CEE

An enhanced commitment to the electronics industry

Dow Chemical Canada Inc. focuses on electronics and telecommunications

The rapidly changing business environment in the 1980s has caused most major companies to shift towards specialties and has encouraged an alignment to whole markets, rather than to specific products. In keeping with these developments The Dow Chemical Company, one of the world's largest chemical and plastic suppliers, has begun focusing on one of the most rapidly growing specialty industries—electronics and telecommunications.

Dow has been a leading supplier to this burgeoning industry for several years, although most of its activity has been concentrated in basic chemicals

Dow's Carl Lucas, Industry Development Manager, left, and Senior Field Sales Representative Larry Burke, with a static dissipating Ethafoam® shipping container

continued on page S20

Static in the electronic office

ESD can make computers sick, and conductive carpeting can cure before the cause kills.

By Richard Speak,
Director of Manufacturing,
heuga Canada Ltd.

Contrary to that automation chestnut 'computers never get sick' any office or production manager knows that they do—often and expensively. The problem is that key components of equipment, like computers and advanced communication systems, are highly sensitive to the effects of Electro Static Discharge (E.S.D.). Whereas the human components of the electronic office are usually insensitive to the discharge of less than 3,000 volts, the ubiquitous micro chip can be damaged by much lower charges, in some cases as small as 50 volts.

While the hazard is fully recognized, the causes and possible solutions are less well appreciated. An understanding of the causes of static is a necessary first step to devising solutions to the problem of E.S.D.

What Causes Static?

When two dissimilar materials rub against one another the conditions for the accumulation of static charges exists.

How big the accumulated charge becomes will depend on a number of factors, such as:

- how long the rubbing contact of the two materials lasts
- how well insulated the materials are
- the relative position of the two materials in the 'triboelectric series'

A 'triboelectric series' ranks materials to indicate relative propensities to gain or lose electrons in a static-causing situation. Pairs of material far apart on the scale are likely to generate larger charges than pairs situated close to one another in the scale.

Unfortunately the typical electronic office is full of material 'pairings' well separated in the triboelectric series and capable of creating large voltage charges. Examples are:

- Wool suits and polypropylene upholstery
- Nylon stocking and acrylic upholstery
- Neolite shoes and nylon carpeting
- 'Plastic' envelopes and paper contents and the list goes on.

Possible Solutions to Static Problems

The theory states that static is caused when two *dissimilar* materials are in contact. Can we create a 'one material' environment? The only situation to which this solution has been generally applied is the hospital operating room where everything is cotton; clothing, masks, shoe covers, sheets and so on. Obviously not an approach that can applied universally.

Another possible solution lies in fact that high humidities provide an environment that allows static charges to dissipate thanks to the conductive property of water. Unfortunately neither the human nor electronic components work well in high humidities, and in any event they are difficult to maintain in a climate like ours.

Computer manufacturers, who are among those most concerned with the damaging effects of E.S.D., have identified conductive floor covering as a vital part of the solution to the static problem.

For a floor covering to fulfil this function it must have the following properties:

Low Static Generation Propensity The carpet itself should not be a source of large static charges when people walk on it.

Conductivity Across the Face of the Carpet If a carpet has this property it will diminish high local charges by allowing them to spread across the entire carpeted surface.

Conductivity Through the Carpet A carpet should be conductive through to its backing. That way, regardless of the source of the static build up, the charge is able to drain away harmlessly.

Decay Time All this must take place quickly. An electric charge must 'decay' or dissipate to a harmless level in a time measured in fractions of second.

The heuga solution

heuga has responded to the challenge posed by the demands of the electronic environment by developing heuga Electron XL carpet squares.

In doing this, heuga has made no use of topical treatments available, which lack durability and may contribute to soiling. The conductivity properties of heuga Electron XL are built permanently into the product by:

- Adding additional conductive elements to a nylon face of fourth generation Antron XL by Du Pont
- Anchoring this yarn firmly in a conductive backing
- Modifying its Mexphalt Conture backing to provide conductivity and a permanent electrical path from the face of the tile to its back

The result is a material that exceeds all current standards established by computer manufacturers for electronic offices—which lets you give up the static without giving up the carpet.

heuga has published a Technical Manual and full colour brochure which illustrates in more detail the use of heuga Electron XL carpet squares and the many advantages inherent to the product. To obtain a copy circle 299 on the reader service card. CEE

continued from page S17

and plastics. Realizing that sales could increase dramatically by satisfying quality requirements through the production of specific electronic grade product line extensions, the company has introduced several new electronic grade process chemicals and resins include PRELETE® defluxer solvent, STRIPTRON® photoresist stripper, QUATREX® epoxy resins and DOWEX® monosphere ion exchange resins.

As a result of such substantial commitments, particularly over the last year, Dow today markets products and services that play an integral role across the broad industrial spectrum, from the production of passive and active devices to the final protective packaging used to ship the peripherals. Dow intends to build on this existing chemical, material and fabrication base through a very active R&D program, not only to sustain leadership and growth, but to accelerate development in new emerging electronic applications.

New projects initiated by Dow in its Central Research Laboratories include opto-electronic systems, plastic microlayer coextrusions, ultra-high-temperature plastics, composites and ceramics, submicron particles and static control and EMI shielding products.

The development of specialties, however, requires strong outside-in orientation; a market-driven approach which, by analyzing industry trends, relates research activities *directly* to customer needs and problems. In responding to this challenge, Dow Chemical Canada Inc. has named Carl Lucas as Industry Development Manager to the Electronics and Telecommunications Industry. His role is to act as a liaison between Canada industry technology needs and Dow's extensive research and development capabilities.

Dow's commitment to electronics was recently demonstrated at the Ottawa High Technology Show where its booth won a 'Best Display' award. "Receiving the award was, of course, very satisfying but the most gratifying result of the show was the positive response from customers visiting the booth, as well as the quantity and quality of leads generated," says Lucas. "Since this show, we've planned several exciting joint development initiatives with Canadian accounts aimed at new technology to meet unique evolving applications." CEE

Cleaning solvents

Safety and reliability lead to wide acceptance for fluorocarbon solvents

Motorola Canada Limited is one of an estimated 70 per cent of Canadian electronic and telecommunications manufacturers now dedicated to fluorocarbon solvents as their principal production cleaning agent. The world's largest maker of mobile communications systems insists on safe and reliable solvents, as is typical in their industry.

Motorola uses Du Pont's Freon® TES in an on-line vapour degreasing Detrex unit. Soldered circuit boards for their reliable two-way radios are immersed in boiling TES for five minutes to remove fluxes, oils and dirt, then spray rinsed and vapour rinsed. The sensitive boards emerge crystal clean and totally undamaged, according to Motorola tooling supervisor Derek D'Andrade.

Its been estimated that in the 20 years they have been available, fluorocarbon cleaning solvents have been enthusiastically accepted by most of Canada's makers of electronics and telecommunications equipment and systems.

More than half of the plants currently using the fluorocarbon cleaning systems available have converted from other systems despite conversion equipment price tags of up to $65,000. Further, nearly nine out of ten new cleaning systems purchased are for those driven by fluorocarbons, and these too are somewhat premium priced. There are several reasons for the acceptance according to Douglas D. Stohmann, a marketing representative for Du Pont Canada's Industrial Chemicals Division. "Safety, performance and cost are the criteria most manufacturers examine in selecting solvents and there is no doubt that the fluorocarbons are solvents of choice if these criteria are vital," he said.

"From a safety standpoint, fluorocarbons are completely non-flammable throughout their full evaporation range, including pressures and temperatures reached in degreasing operations. "Except for carbon dioxide, this family of compounds have one of the highest assigned TLV/TWA, (threshold limit value/time weighted average), values at 1000 ppm by volume in air as established by the American Conference of Governmental & Industrial Hygienists." said Mr. Stohmann.

This is a measure of vapour concentration in air to which nearly all workers may be repeatedly exposed day after day for a normal 8 hours and for a 40 hour week without adverse effect. In comparison, the TLV/TWA ratings for methylene chloride are 100, for methylene chloride azeotrope 140 and for methyl chloroform 215-270 depending on inhibitor formulation.

"Its simply that with Freon the work environment is safer and more comfortable for the people who do the actual work," said Mr. Stohmann. "The lower boiling point of fluorocarbons keeps the plant cooler and the material itself has very low toxicity values."

Performance or effectiveness of fluorocarbons is well documented. Their low surface tension (17.3 dynes/cm) allows rapid and thorough adherence to surfaces and crevices. In turn this promotes total cleaning. Co-solvents provide fluorocarbons with physical property flexibility—methyl alcohol, for instance, increases ability to remove ionic salts which is a critical characteristic particularly for makers of printed wiring assemblies.

In an independent test program first published in early 1985 by Texas Instruments Inc., fluorocarbon was clearly established as that company's "preferred" in-line defluxing solvent where high reliability of finished product is wanted. Said the TI report, in part, fluorocarbon has ". . . superior compatibility with components, plastics, materials of construction, and marking inks". It adds that fluorocarbon has ". . . retention of composition during use compared with other tested solvents".

"The stability of fluorocarbons is remarkable," said Mr. Stohmann. "Du Pont's Freon TES and Freon TMS, for instance, are very gentle with most metals, plastics and elastomers, common to the electronic industry. Well stabilized, they will not react with usually active metals such as zinc or magnesium, also common materials for many manufacturers," he said. "This means that all components of a product can be put in place for mass soldering without the need for adding-on components at extra labour cost."

Another bonus for most users is the low boiling point (from 36.2°C to 48.9°C) of fluorocarbon compounds. "The result is that systems use less energy to recycle the solvent," said Mr. Stohmann. "Cooler cleaning temperatures also translate into reduced air conditioning and ventilating expense." He added that systems using other solvents with higher boiling points may consume up to twice as much solvent.

Low solvent consumption has benefits beyond dollars and cents. In the case of the Texas Instrument analysis they noted "it helps produce a safe working environment". They also reported that with good maintenance, proper defluxing procedures and the use of a halide detector, solvent consumption for one product line dropped from 13 drums a month to 5 drums, and then a single drum. "They gained a 90 per cent cut just through a good understanding of equipment and system chemistry," said Mr. Stohmann.

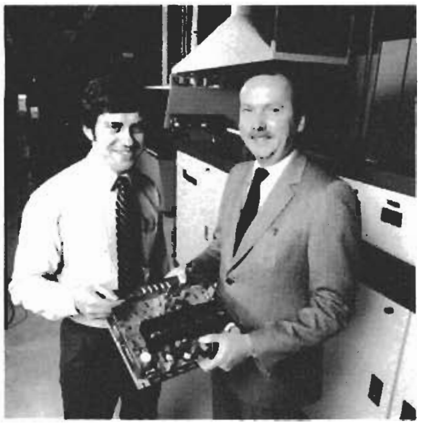
Cost benefits with fluorocarbons are certainly measurable. The Texas Instrument study, for instance, projected an annual overall system cost savings of roughly 50 per cent if fluorocarbon, rather than another solvent, was selected.

"Another further major source of cost savings lies in the efficiency inherent in recycling fluorocarbon," said Mr. Stohmann, "in most closed systems we find that even large reservoirs need less than two drums of added solvent for a two-shift operation. Unlike other solvents, fluorocarbons are environmentally harmless and can be disposed of with no special handling costs."

"In fact, most users can realize income from the sale of contaminated fluorocarbon to recovery specialists who may re-sell 'purified' material to firms in industries with less demanding standards for parts or material cleaning."

However it can take some time for fluorocarbons to accumulate as waste-product. Because of their stability and resistance to hydrolysis, they need few stabilizers and their original composition can be restored quickly merely by adding fresh alcohol until the wanted specific gravity is regained.

Fluorocarbons have gained a wide acceptance in just 20 years, even beyond their stellar role in the electronics field. Manufacturers of pacemakers and other human implant prostheses are now routinely cleansed with fluorocarbons before sterile shipment. "And in hospitals, doctors use the material to wash skin before surgery," adds Mr. Stohmann. CEE



Manufacturing engineer Al Hyslop of Northern Telecom's Bramalea facility (left) with Doug Stohmann, Du Pont Canada marketing representative for solvents stand in front of an in-line vapour degreaser equipped with Freon TMS to clean circuit boards.

Chemicals for the service technician

By Larry S. Davis,
regional sales manager,
Chemtronics Inc.

Chemicals that are designed specifically for the electronics industry are as useful a tool as the frequency generator, video analyzer, multimeter, oscilloscope or screwdriver. Used correctly, the proper chemical can save the technician hours of valuable time while increasing productivity and cost efficiency.

Electronic chemicals can be classified as degreasers, solvents, flux removers, lubricants, contact cleaners, tuner cleaners, antistatic sprays, freezing agents and conformal coatings. Most of these consist of various blends of fluorocarbons and other solvents.

Generally, there are two types of fluorocarbons used in aerosol contact and control cleaners: Freon® 11 and Freon TF®. These are cleaning agents that dissolve oils and greases but will not adversely affect most metal contacts or common plastics. Freon 12 does not have the cleaning properties of Freon 11 or TF, but is used primarily as a circuit cooler.

At earlier stages in the development of electronics, carbon tetrachloride and trichlorethane were the most commonly used cleaners. However, both of these solvents are highly toxic and very limited in usage. Fumes from carbon tet were more than 200 times as toxic as those of modern cleaning agents. Freon 11 and Freon TF are non-toxic and stable and have no adverse effects on plastic.

Tuner cleaners

Defective TV tuners are accountable for a wide variety of problems: snowy pictures, noisy reception, loss of sound and/or picture, flashing picture and picture distortion.

Dirty or corroded contacts are the primary cause of tuner cleaner and lubricant is essential in eliminating most of the problems associated with poor tuner contacts. A tuner "wash" with a blend of fluorocarbon solvents is the ideal first step in tuner maintenance. Used in aerosol form, this concentrated formula degreaser removes oil, dirt and gunk from contacts and eliminates built-up oxidation while leaving parts and contacts totally clean.

Using a tuner wash is simple. Remove the tuner, then open and carefully spray the contacts, rotating the tuner as you spray. The force of the spray alone will-help eliminate much of the dust and dirt. Be certain that the tuner wash you use is a non-residue cleaner that is safe for plastic parts.

The second step in tuner maintenance is just as important as the first. An application of a good cleaner/lubricant will help keep your tuner maintenance free for long periods of time. The most effective cleaner-lubricants contain small polishing particles that remove oxidation and corrosion from contacts, leaving the tuner in like-new condition. A valuable additive to tuner cleaners is a chemically inert lubricant that protects contacts and prolongs tuner life.

Tests have proved that properly lubricated tuners can last for as long as 40,000 revolutions, whereas the typical life of an unlubricated tuner is 18,000 revolutions.

Proper application of a cleaner/lubricant is similar to that of a tuner cleaner. Spray all contacts, rotate, check stator contacts to assure they press against rotor contacts with enough pressure to ensure positive contact and good cleaning action. For periodic maintenance, use a light duty cleaner lubricant.

Many customers who had given up on their televisions because of snowy pictures are amazed to find their sets working like new after an experienced technician has performed his "chemical magic."

continued on page 25

continued from page 22

Component/circuit coolers

Detection of defective components that are heat sensitive can be simplified by the use of circuit coolers. Failure of resistors, transistors, capacitors and other component parts is frequently induced by heat. A spray application of a refrigerant, usually Freon 12, cools circuits instantly to −65°F, (−54°C), in many cases temporarily restoring the suspected component. Thus, the thermal intermittent is quickly and accurately pinpointed allowing for a quick replacement.

There are other uses for component coolers as well. To locate cracks in PC boards, for example, spray the copper foil circuitry. This will cause it to frost and turn white, exposing the crack. When soldering heat sensitive components, spray and chill components before soldering for maximum protection.

To prevent cold solder joints, instantly cool the fresh solder joint to prevent wire movement before the solder solidifies. Coolant spray can also be a good way to limit transformer damage.

Flux removers

A good flux remover is an exceptionally useful product in electronic production, rework and repair. Again, a Freon solvent blend in aerosol form is ideal for removing flux after soldering. The aerosol is additionally important here, as it provides a constant supply of fresh solvent to prevent re-contamination. This product is available with CO_2 as a propellant, helping to remove stubborn contaminants without brushing or scrubbing.

When selecting a flux remover you should consider the type of rosin to be removed, ease of application, and operator safety.

High voltage insulator

Another beneficial addition to the technician's tool kit is a good, all-purpose insulating spray. This differs from the previously discussed chemicals as it contains a hard, insulating acrylic resin. When applied, this acrylic coating is highly resistant to environmental extremes such a moisture, oils, acids and alkalis. It stops arcing and corona shorts, insulates against RF high-voltage leakage as high as 25,000 RF volts, leaving a protective coating that permanently restores insulation. A good, high-voltage acrylic insulator such as No-Arc is recommended for RF transformers, motors, electrical wiring and PC boards.

Audio equipment maintenance

The increase in the number and variety of audio/video products has been accompanied by an increase in audio/video maintenance. An important requirement for chemicals used in this area of electronic maintenance is non-contact cleaning. It is imperative that delicate magnetic heads and computer discs be handled as infrequently as possible.

Magnetic Head/Disc Cleaner contains Freon solvents and isopropyl alcohol that are specially formulated and packaged in aerosol containers. When sprayed on equipment, this chemical safely removes dirt and oxide buildup from audio/video heads and computer discs. This product is non-residual, evaporates instantly, and can be used to maintain rollers, guides, capstans and tape transport components.