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Quality and Reliability - Electrostatic Discharge

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Electromagnetic Compatibility and Power Department

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1. General

1.1 Purpose

This practice describes the origin and nature of electrostatic discharge (ESD) and sets forth preventive measures to minimize its probability.

This practice is being reissued to

- Incorporate the latest ESD references
- Introduce terminology changes
- Update ESD practices.

1.2 ESD Damage

The probability of damage or destruction from ESD is greater than most people realize. ESD damage goes unnoticed because the threshold for human sensation can approximate 3,500 volts. ESD damage to electronic devices can easily occur at less than 500 volts. For this reason, an individual may not feel a "shock," but electronic devices or assemblies will.

1.3 What is ESD?

1.3.1 Overview

ESD is a rapid, spontaneous transfer of electrostatic charge induced by a high electrostatic field. Usually, the charge flows through a spark between two bodies at different electrostatic potentials as they approach one another. The most familiar example of this is the "shock" a person might receive upon touching a metal object after walking across a carpeted room, particularly during the normal heating (low humidity) season. At lower levels of static charge there may be no sensation indicating that ESD has taken place, but the energy flow may be sufficient to damage or destroy a static sensitive electronic devices or circuit card assemblies. A static charge of several thousand volts can be produced by contact and separation and retained by the human body. Static discharge occurs when the charged person touches another person, a metal of a different potential, or a grounded object. Static charging is a natural phenomenon with extremely complex characteristics depending on material composition and structure, environment, and conditions of contact. The ESD models, origin and nature of ESD, and control measures are described TR-NWT-000870,[1] *Electrostatic Discharge Control in the Manufacture of Telecommunications Equipment (a module of RQGR, FR-796).*

1.3.2 Equipment Damage or Degradation Caused by ESD

Damage or degradation to electronic equipment by ESD is caused when a charged object, usually a person, makes contact and discharges the stored body charge into the equipment. It can also be caused by electrostatic coupling, e.g., induction from a nearby field. In addition, electronic devices can accumulate a static charge during transport which, upon discharge to ground, can produce damage. Total isolation or shielding of people, equipment, or circuits to protect against ESD is not as yet possible.

1.4 What Causes ESD?

A static charge is generated whenever two materials come into contact or are rubbed together and then separated. This action results in a charge buildup due mainly to the transfer of electrons from one material to the other. The accumulation of charge causes a static potential to develop. ESD occurs when the accumulated charge is discharged to anything with a different electric potential.

1.4.1 Static Charge Accumulation

The accumulation of static charge and its tendency to cover all conducting surfaces is what sets the stage for ESD damage. If a charged conducting object contacts an uncharged conducting object, the charge will be transferred to equalize the potential. It is important to note that we are not necessarily talking about a voltage with respect to ground, but rather a voltage or potential difference between any two objects.

1.4.2 Magnitude of Developed Charge

The magnitude of the developed charge depends on the material's properties, the method of charge generation, and the rate of leakage. When the rate of generation equals the rate of leakage, no further charge can be developed. The time the charge remains on a charged object depends on the rate of leakage.

1.4.3 Triboelectric Series

The behavior of materials regarding static charge can be determined by their relative position in what is known as the Triboelectric Series. The Series provides a rough indication of the Triboelectric properties of materials. Some variation in the listing occurs with environment and variations in material properties. Table 12-1 shows the Triboelectric Series of some common materials. The polarity (+ or -) of the static charge generated on each of the materials and the relative magnitude of the charge can be obtained from Table

12-1. The further apart the materials are located in the Triboelectric Series, the greater the static charge they can develop. A material at the top of the listing acquires a positive charge when contacted with any material below it. A classic example is rubbing a glass rod with wool. The glass assumes a positive charge and the wool a negative charge. Many of the materials are commonly used in the semiconductor industry by both manufacturers and users.

1.4.4 Personnel Charge Generation

A person walking across a floor, sliding on a chair, or rubbing a work surface can generate thousands of volts of static potential. Devices or circuit card assemblies sliding around in containers can also develop damaging static potentials. The static charge level or potential that can be generated is affected by such factors as relative humidity, air flow rate (in the case of air containing particulates), floor materials, furniture, and clothing. These factors exist in almost every situation. In dry conditions, such as in a heated building during the normal heating season or in naturally arid climates, the leakage rate is reduced and extremely high static potentials can be developed. See Bellcore SR-3700,[2] *Economic Impact of Humidifying Telecommunications Central Office: The Humidity/ESD Study.*

1.4.5 Other Factors

Other factors which affect the charge level are not so apparent. These include the design of manufacturing equipment and the materials used in the construction of such equipment, chemicals and other materials used in manufacturing processes, and packing and shipping materials.

1.5 Who Causes ESD?

Everyone who has contact with circuit packs, integrated circuits, or individual devices in all stages of manufacture, handling, storage, shipping, installing, testing, and maintenance can damage or degrade these units by ESD. Static electricity can be generated by simple everyday tasks. The following values indicate the magnitude of potentials that can be generated on personnel as a result of triboelectric charge at low humidities (below 20%):

- Walking across vinyl floor — 12,000 volts
- Walking across a carpet — 35,000 volts (For untreated residential type carpet)
- Walking across a carpet — 3,000 volts (For commercial treated carpets)
- Working at a bench — 6000 volts
- Polyethylene bags — 20,000 volts

- Handling foam containers 18,000 volts
- From a computer monitor 20,000 volts

1.6 Other Sources of ESD

Another common source of ESD is the cathode ray tube (CRT) computer monitor. Some CRT monitors may have screen voltages of over 20,000 volts. Ungrounded personnel can be charged by induction when near a CRT and discharge to sensitive circuit card assemblies. Ungrounded devices and circuit card assemblies can become charged when brought near a CRT monitor. ESD damage can occur when the device or circuit card assembly is grounded or touched to an object with a different potential. Therefore all devices and circuit card assemblies should be kept at least three feet from CRT monitors.

Personnel using headsets have received ESD shocks from CRT monitors during power -on or power-off occurrences. ESDs from CRT monitors can be alleviated by using electrostatic shielding such as external grounded filter glare screens or CRT monitors with built-in grounded filter screens. It is suggested that shielding screens be purchased with an visual indicator showing that the screen is actually grounded and functional.

Other sources of ESDs are static generators such as ordinary plastic sheets or bags, the separation of labels or tape from backing or roll, ungrounded storage racks, rolling chairs and carts, conveyer belts, hand tools such as metal pliers or cutters, (held in the hands of a charged person), and soldering irons, various types of production equipment such as automatic testers, wave solder machines, insertion machines, and surface mount machines. Some plastic products such Styrofoam and some Rubbermaid® plastic products are particularly hazardous charge generators and should be kept from the work area.

Electrical transients, electromagnetic interference (EMI), can be caused by equipment such as large inductors, i.e., solenoids, motors, faulty test equipment, and faulty grounds. These could include vacuum cleaner motors and floor polishing machine motors. Improperly grounded electrical outlets can cause EMI from electrical machines. Avoid using any machine that could interfere with the operation of telecommunication equipment.

2. Device Susceptibility

2.1 Component Sensitivity

All components are sensitive to ESD. The degree of susceptibility and the level of sensitivity are governed by the circuitry and feature structure of the device, the design of the circuitry, and the manufacturing process applied to the device. Fine line designs, small junction features, and thin dielectric structures are particularly sensitive to the high fields and/or discharge pulses associated with ESD. Devices mounted on circuit card assemblies may not have less susceptibility. A more quantitative look at susceptibility is presented in Table 12-2. Here various device types are shown with the range of voltages that can cause ESD damage to unprotected (bare) devices.

2.2 ESD Failures

ESD failures are not always readily apparent; ESD failures often show no visible damage. Failures range from catastrophic to intermittent to subtle electrical degradation that affects operating characteristics. ESD damage is not limited to integrated circuits. The failure effect in film resistors due to ESD is a change in resistance value and tolerance. Changes in tolerance are most noticeable in precision film resistors. The very nature of electronic devices that makes them so useful (small size, low voltage, low power) is also what makes them so susceptible to ESD. Thin film capacitors used on hybrid integrated circuits can be damaged by ESD.

3. Equipment Susceptibility

3.1 General

There is more to equipment susceptibility than just the damage done to electronic devices. ESD can produce noise transients within the system wiring causing malfunction; for example:

- A terminal sends the wrong data to the main computer
- Partial or complete loss of data
- Memory in the main computer is changed causing parity errors
- Complete loss of a program
- Printers overprint or print garbled data
- Disk and tape units "write" incorrect data.

These typical malfunctions can be caused by the Electromagnetic Interference (EMI) generated when ESD occurs. This wave of EMI, like a radio wave, spreads out in all directions from the point of static discharge. When the wave reaches conductive objects, a small electrical current is generated. These currents can cause the aforementioned malfunctions.

3.2 Shielding

Metal housings for the equipment can be helpful in reducing EMI, but the energy can propagate into the circuits through a discontinuity in the housing. Molded plastic cases may prevent damage from direct static discharges, but may allow damage or upset that is induced by the radiated fields because plastic cases typically provide poor shielding to EMI. In addition, the cables which interconnect the equipment may typically pick up the interference indirectly, regardless of the type of enclosure.

3.3 Static Charge Accumulation

While the problems just discussed are by no means trivial, they are only part of the story. In addition to the damage caused by direct discharge of static electricity, other problems can arise just from the accumulation of static charge, even if ESD does not occur. With computers and related equipment, charge accumulation can cause problems such as printer malfunction and paper jamming, and can cause dirt and other contaminants to be attracted to read/write heads and magnetic recording surfaces (disk and tape).

4. Preventive Measures

4.1 ESD Protection and Prevention

There are four steps for effective ESD protection and prevention. These are

- Identify the problem
- Educate all persons involved
- Implement corrective action
- Monitor progress and follow-up as required.

4.2 ESD Control Procedures

The key to preventing ESD damage is to avoid the buildup of static charge. The best way to do this is by following careful handling and transport procedures:

- Wear an approved grounded wrist strap when handling bare circuit card assemblies. The strap shall be tested on a daily basis to ensure its operability. See Section 5.
- Package and transport all circuit packs (even those presumed defective) in approved protective static dissipative packaging.
- Maintain a static safe environment for the handling of circuit card assemblies and other electronic equipment, making sure that all containers or packing materials are marked with ESD warning labels. All facilities should be audited on a regular basis to monitor ESD control.
- Minimize the handling of circuit card assemblies and store them in static dissipative packages. Remove the circuit card assemblies from their protective packaging at the frame only after putting on a properly grounded strap.
- Handle circuit card assemblies by the front faceplate. If additional support is needed, use the outermost top or bottom edge. Be careful not to touch any components or conductive paths. Never grab the circuit card by the connector end (gold fingers).
- Keep synthetic fibers, plastics, foams, etc., and other charge generators, out of the environment (three feet away) where circuit card assemblies or integrated circuit devices are going to be handled or stored.
- Implement a ESD control training program for all personnel who may handle sensitive devices or operate electronic systems.
- Avoid using carpeting in equipment rooms or circuit pack storage areas, e.g., controlled environment vaults (CEVs), huts, central offices (COs), etc. When possible, this should include off-premises equipment areas.

5. Wrist Straps

5.1 When to Use

A. Wear properly grounded wrist straps when removing, inserting, or handling circuit card assemblies. The wrist strap cord should have a 1 megohm ±20% resistance in series at the wrist cuff end and a suitable device such as a banana plug or an alligator clip at the opposite end for connecting to a designated ESD post or jack. Most commercial wrist straps have a molded-in 1 megohm resistor near the wrist cuff end. The wrist strap must be snug fitting and make electrical contact with the skin. This provides a path to drain the static charge from the body.

B. Generic Requirements document GR-1422-CORE,[3] *Generic Requirements for ESD-Controlling Wrist Straps,* may be used to qualify wrist strap suppliers.

C. Requisites for manufacturers of wrist strap testers are described in GR-1418-CORE,[4] *Generic Requirements for Wrist Strap Testers.*

5.2 How to Test a Wrist Strap

- With the cord attached to the cuff, place the back of the cuff (180 degrees away from the backplate) over the middle finger and forefinger and close to your thumb gently to hold the cuff while allowing the cord to hang below.
- Using your other hand, plug the banana plug into the jack on the wrist strap tester.
- With your free hand, press the touch plate and observe the LED indicators.
- If the pass indicator lights, adjust the cuff to fit with slight pressure around your wrist and test the wrist strap assembly on your wrist by pressing and holding the touch plate while flexing the cord to make sure it is not making intermittent connection.
- If the fail indicator lights, rotate the cuff 180 degrees placing the metal back plate cover over the middle finger and forefinger and close the thumb gently over the cord connection.
- With your free hand, press the touch plate and observe the LED indicators.
- If the pass indicator lights, replace the cuff and start over at the first bullet step.
- If the fail indicator lights, replace the cord and start over at the first bullet step.

> **NOTE —** There may be an occasion when your skin is so dry that the cuff will not make electrical contact and every wrist strap fails. In this case, use an approved moisturizing lotion to wet the skin.

The above tests can be done using a voltohmeter to measure resistance. The resistance reading should be between 1 and 10 megohms with a full scale resistance range of 10 to 20 megohms. The meter should have a full scale accuracy of at least ±10%.

5.3 When to Test a Wrist Strap

Wrist straps should be checked daily unless the failure rate or conditions indicate a need for it to be tested more often. To assure proper circuit continuity and resistance, check end to end with a wrist strap checker.

5.4 Spare Wrist Straps

Every equipment facility should have an adequate number of new spare wrist straps. The minimum would be one spare for each technician in the facility. All technicians are responsible to have their own working wrist straps available when handling bare circuit card assemblies.

6. Static Dissipative Packaging Materials

6.1 General

Untreated cardboard boxes, molded foam containers, plastic bags, loose fill, and cushioning material can become charged with static (charge) electricity. These items should not be used to package circuit packs for storage or shipment. All packing materials should be packaged in static dissipative containers, and meet the requirements of GR-1421-CORE,[5] *Generic requirements for ESD-Protective Circuit Pack Containers.*

6.2 A Totally Enclosed Container

All circuit pack containers should totally enclose the circuit pack with no holes or openings present.

6.3 Warning Label

Packages should have a warning label to indicate that contents are susceptible to damage from static electricity. (See Section 11-3 for a description of the ESD protective symbol.)

7. Environmental Requirements

7.1 Relative Humidity

Reports of static electricity problems generally increase with atmospheric dryness. In central offices these reports are most frequent when the relative humidity is below the 20%. Merely raising relative humidity never completely alleviates the static electricity problem. However, raising the humidity may not be a cost effective mitigation method when compared to using proper ESD control procedures. (See Bellcore SR-3700.) Periodic service checks of the humidification equipment should be scheduled to insure that the units are functioning properly at all times.

7.2 Operating Temperature Range

Operating the building within the recommended wide-band temperature limits for heating and cooling (e.g., 65°F to 80°F) reduces the amount of outside air intake needed for cooling. For more information, see SR-3400,[6] *Economic Impact of Increasing the Operating Temperature Range Within the Telecommunications Central Offices.* Both high and low humidity conditions are alleviated. However, if the humidifiers are inoperative at any time during the normal heating season, the relative humidity can become less than 20%. Therefore, ESD control procedures must be used at all times.

7.3 Floor Treatment

7.3.1 Use of Carpets

Walking on carpeted floors can generate static electricity, however carpets also store dirt and particulates. Although modern static dissipative carpets adequately mitigate ESD, they are a source of dirt and particulates that can harm electronic equipment. Therefore, the use of floor carpeting in telephone equipment rooms, and also in rooms containing equipment connected to telephone network equipment, **is not recommended**. Static dissipative carpeting has been recommended for use in administrative office space, but even this type of carpet should not be used in equipment rooms or in rooms with equipment electrically connected to the telephone electronic switching system. For more information, see GR-1424-CORE,[7] *Generic Requirements for ESD-Protective Floor Covering.* and GR-1423-CORE,[8] *Generic Requirements for ESD-Protective Floor Finishes.* ESD floor covering is only effective when used in combination with ESD-protective footwear or shoe grounders. BOTH shoes **MUST** use the heel or toe grounders to be effective.

Carpeting with metal strands is not recommended since there is the possibility of some metal strand breaking free and possibly causing equipment problems.

7.3.2 Floor Finish Use

Static dissipative floor finishes can minimize charging of personnel as well as dissipate the charge from conductive bodies, as well as, ESD-protective chairs, carts, and other materials. ESD footwear or shoe grounders should always be used in combination with the floor finish. BOTH shoes MUST use the heel or toe grounders to be effective.

7.4 Floor Covering Electrostatic Performance

Perform a resistivity level test with a suitable megohmeter for measuring surface resistance on the floor covering and furniture materials. Surface resistivity is a factor in limiting electrostatic voltage build-up on people. The test methods specified in the ESD Association Standard, EOS/ESD-S7.1 may be used to measure floor surface resistance. For flooring, the acceptable resistance range is $1x10^6$ to $1x10^{10}$ohms. All floor finishes and floor coverings should meet the requirements in GR-1423-CORE and GR-1424-CORE.

7.5 Air Filtration

Review the building's air filtration system to insure that it meets or exceeds the minimum requirements (see Section 2.2, *Equipment Room Filtration*, in BR 781-810-885[9]). For buildings in clean suburban or rural locations, filters with a removal efficiency of 65% (American Society of Heating, Refrigeration and Air-conditioning (ASHRAE) dust spot rating) should suffice. In densely populated urban areas, filters with an ASHRAE dust spot rating of 85% or greater should be used. For highly polluted industrial areas, filters with an ASHRAE dust spot rating of 95% may be required.

During periods when the outdoor dewpoint temperature is less than 20 °F, the intake of outdoor air should be kept to a minimum in order to avoid excessively dry indoor conditions. The minimum recommended ventilation rate is an average of 1/4 air change per hour, or 15 cfm per person, whichever is greater (see Section 5.1, *Switching Equipment Rooms*, in BR 781-810-885)

8. Storage, Movement Within an Equipment Area, and Shipping

8.1 Storage

All circuit card assemblies should be received and stored in containers that meet the requirements of GR-1421-CORE. All circuit card assemblies having sensitive electronic circuits should have approved ESD warning labels. The labels indicate that special handling is required (See Section 11). Circuit card assemblies should be left in their individual ESD protective containers and stored in grounded metal cabinets. These containers will provide protection from both mechanical and ESD damage while in storage or transport. The containers will then be available for shipping spare or defective circuit card assemblies back to the Plug-In Inventory Control System (PICS) or the repair locations.

If the circuit pack is to be removed from this container for any reason, the person handling it should be properly grounded. They should be wearing a wrist strap attached to an appropriate ground as indicated in Section 5. ESD shoes or shoe grounders used on a regularly maintained and tested static dissipative floor may be substituted for wrist strap use when special mobility of personnel is required. All personnel grounding systems (wrist straps or footwear) should be tested daily.

8.2 Movement Within the Equipment Area

When removing circuit card assemblies from storage facilities they should remain in their ESD protective containers until ready for insertion in the equipment slot or shelf. A suggested method for handling circuit card assemblies is as follows:

1. Remove the circuit card assembly from the storage location in its original ESD protective container. (In the case where a circuit card assembly is stored bare in a special cabinet, it must be inserted into an ESD protective container before transport to the equipment location. The special storage cabinet must be equipped with these spare containers. You will have put on your wrist strap and connect it to the cabinet ground before removing any bare packs and inserting them into ESD protective containers. Care should be used so as to not physically damage them during removal. When finished, disconnect your wrist strap.)
2. Carry the circuit card assembly in its protective container to the equipment location.
3. Put your wrist strap on and attach the banana plug end to an appropriate equipment ground. Usually the equipment manufacturer will have provided a labeled jack for your wrist strap, however this may not always be the case. (There may be times when you will need to use an alligator clip with the wrist strap cord banana jack to make a

proper connection to ground.) Refer to Section 5 for additional information. Report any equipment that does not have properly marked ESD jacks (receptacles) for wrist straps.

4. Open the protective container. If the circuit card assembly is in a plastic bag, remove it and place the circuit card assembly on top of the bag in the open container.
5. Remove the defective circuit card assembly from the slot or shelf and place it on the open cover of the protective package. Never place a circuit card assembly on the bare floor.
6. Insert the good circuit card assembly into the slot or shelf.
7. Insert the defective circuit card assembly into the ESD protective container for return to PICS or repair location. If a bag was used to hold the circuit card assembly in the protective container, place the circuit card assembly in this bag and then into the protective container.
8. Disconnect your wrist strap.
9. Carry the circuit card assembly in its protective package to the ESD workstation for processing and shipping. If for any reason the protective package is opened at the ESD workstation you must wear your grounded wrist strap. See GR-1419-CORE,[10] *Generic Requirements for ESD-Protective Workstations.*

8.3 Movement Within the Equipment Area (Alternate Procedure for Movement of Bare Circuit Card Assemblies)

In this alternate procedure all bare circuit card assemblies will be transported in a special **ESD Field Service Kit**. The kit consists of a static dissipative plastic sheet type work surface with two large pockets, each large enough to hold a switching circuit card assembly. The work surface has a ground terminal to connect a wrist strap and a ground wire connection. The kit comes complete with a wrist strap and ground wire with alligator clip if required. Use the following procedures:

1. Connect the field service kit ground wire to the cabinet ground. Put on your wrist strap and connect it to the field service kit ground. Carefully remove the bare circuit card assembly from the cabinet, being careful not to damage components upon removal, and put it in one of the field service kit pockets. Close the flaps on the kit. Disconnect the kit ground from the cabinet.
2. Transport the field service kit with the circuit card assembly to the equipment location.
3. Connect the field service kit ground wire to the appropriate equipment ground. Usually the equipment manufacturer will have provided a labeled jack for this ground, however this may not always be the case. Refer to Section 5 for additional information.

Report any equipment that does not have properly marked ESD grounding jacks. Put on your wrist strap and connect it to the field service kit ground.

4. Remove the defective circuit card assembly from the slot or shelf and place it in the field service kit spare pocket.
5. Remove the good circuit card assembly from the field service kit. Insert it into the slot or shelf. Close flaps on field service kit.
6. Disconnect the field service kit ground.
7. Carry the circuit card assembly in the field service kit to the ESD workstation for processing and shipping. Connect the field service kit ground wire to the workstation ground. Put on your wrist strap and connect it to the field service kit ground. Have a spare ESD protective container on-hand at the work station for the defective circuit pack assembly. Remove it from the field service kit and put it in the ESD protective container for return to PICS or repair location. See GR-1419-CORE.

8.4 Shipment

All circuit card assemblies should be properly protected before shipment. The ESD protective container should provide cushioning or restraints to assure that the circuit card assemblies are protected from mechanical damage. Defective circuit card assemblies should be handled with the same precautions as a new circuit card assembly, thereby reducing the possibility of added damage. See Bellcore SR-2759,[11] *A View of Packaging, Palletization and Marking Requirements* and GR-1421-CORE.

9. Repair and Modification Locations or Workstations

9.1 General

When performing modification and/or repair operations (i.e., in a PICS or assembly location) all static-sensitive devices, components, and assemblies must be handled in a static-safe work area. Such an area should be equipped with the necessary protective materials and equipment to limit and control static charge accumulation to levels which will not damage sensitive devices or assemblies. This is accomplished by the use of suitable grounding materials and techniques for all conductors (including people) and by the use of ionized air to neutralize static charges on nonconductors. Suitable grounding materials in a work area include wrist straps and static dissipative table tops. Static dissipative floors or floor finishes are an acceptable means to limit charging of people, carts, and chairs, assuming the personnel wear static dissipative footwear and the carts and chairs are also ESD approved. All protective materials should be electrically connected to a common ground system. Work station specifications are described in GR-1419-CORE. See also ESD ADV53.1-1995,[12] *ESD Association Advisory for the Protection of Sensitive Items-Workstations.*

9.2 Static-Safe Work Area

The following recommendations pertain to setting up a static-safeguarded work area:

- All work surfaces must be static dissipative (have a surface resistance of $1x10^6$ to $1x10^{10}$ ohms as measured using ANSI/EOS/ESD S4.1-1990[13] *Standard for Protection of Electrostatic Discharge Susceptible Items-Work Surfaces-Resistive Characterization.*). Bulk static dissipative materials are better than hygroscopic (humidity dependent) materials are more homogeneous because their surface resistance not a function of humidity.
- All personnel handling electronic circuitry must be connected to ground. This is best achieved by a grounded wrist strap which must contact the person's skin. For safety reasons, this ground connection must include a 1 megohm ± 20% series resistance. **Do not** pass a sensitive device to a person who is ungrounded (not wearing a wrist strap).
- All nonconductive items in the work area should be replaced by static dissipative items. This includes trays and other containers, bags, workholders, visual aids, ring binders, tapes, and other shipping, packing, and handling materials. If nonconductive items must be used, ionized air should continuously flow across the work area to neutralize static charges.
- No food should be allowed in a static-safeguard work area. Plastic wrappers and cups (Styrofoam and some Rubbermaid products) are hazardous static charge generators.

9.3 Additional Personnel Precautions

Remove all outerwear such as jackets, hats, gloves, etc. in the locker or entry area before entering the static safe area. Upon entering a static-safeguard work area, a person should first put on a wrist strap to remove any accumulated static charge and follow these precautions:

- Static-sensitive devices and assemblies which are thought to be defective should be handled with the same precautions as good static-sensitive devices or assemblies. If a faulty device or assembly is further damaged by ESD during examination, the cause of the original failure may never be determined. This will also increase the cost of repair or modification and may even make it too expensive to be cost effective.
- All repaired items should be handled with the same protection as new products.
- The use of adhesive sealing tape should be minimized near static-sensitive devices or assemblies.
- Some static dissipative materials are susceptible to a decrease in conductivity as a result of surface abrasion, friction, or heat. Periodic tests should be made to verify conductivity. Static dissipative materials whose resistivity falls outside the limits specified in GR-1421-CORE should be retreated, recycled, or discarded.
- Observe the three foot rule: Personnel who are not grounded should keep back 3 feet from the static safe work area. Do not handle ESDS devices or circuit card assemblies within 3 feet of a computer monitor (video display terminal).

10. Heat Stress Testing

Static dissipative plastic sheeting should be used when performing heat and stress testing as described in Bellcore Practice BR 201-021-001,[14] *Heat Stress Tests, Description and Methods, Stored Program Control Systems.* Static dissipative plastic materials should not be reused for subsequent tests since exposure to the high temperatures will probably cause the static dissipative qualities of the plastic to be reduced. Static dissipative sheeting must also be used to contain dust and contamination during construction and repair activities in close proximity to ESD sensitive systems.

11. Labels

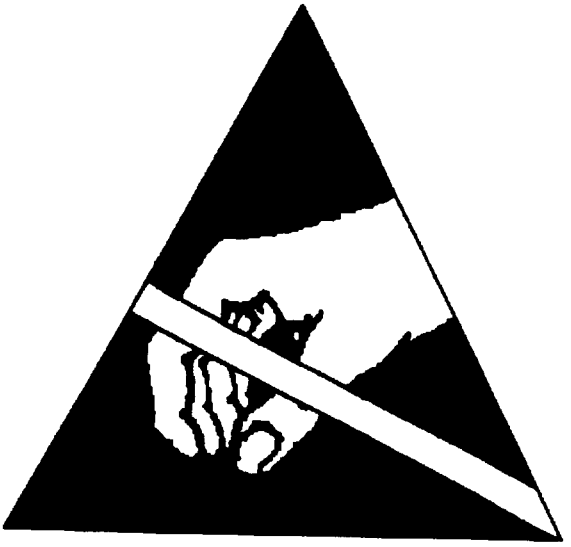

Figure 11-1. ESD Susceptibility Symbol

11.1 The ESD Susceptibility Symbol

The ESD susceptibility symbol incorporates a reaching hand in a triangle with a slash through it and is used to indicate that an electrical or electronic device, assembly, or system is susceptible from an ESD event. The preferred color is a yellow hand on a black background. It should not be smaller than 12 mm (1/2 inch) square.

11.2 ESD Susceptibility Symbol Application

The ESD susceptibility symbol should be used on systems, assemblies, and devices that have sensitivity to ESD events.

The symbol may be incorporated on a sticker used to close or seal ESD protective packaging to indicate that materials inside the package are ESD susceptible.

The symbol shall not be used on materials designed for ESD protective areas, such as smocks, seating, work surface materials, tools and equipment, packaging materials, or personnel grounding equipment. Use the ESD protective symbol described in Section 11.3 in these cases.

11.3 ESD Protective Symbol

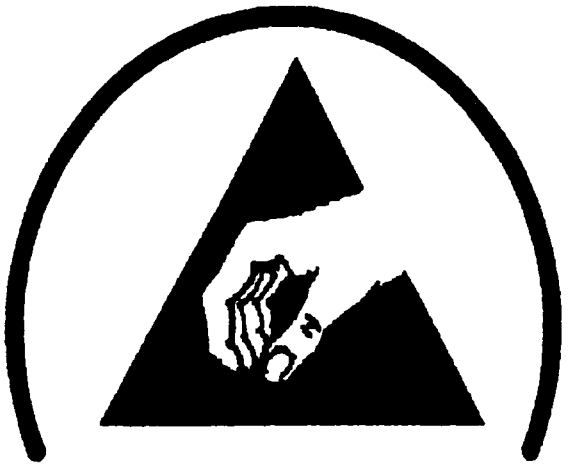

Figure 11-2. ESD Protective Symbol

The ESD protective symbol differs from the ESD susceptibility symbol, by the addition of an arc around the outside of the triangle and the omission of the slash across the hand and the triangle. It should not be smaller than 12 mm (1/2 inch) square.

11.4 ESD Protective Symbol Application

The ESD protective symbol should be used to identify items that are specifically designed to provide ESD protection for ESDS assemblies and devices. Examples of these are packaging, ESD protective clothing and personnel grounding equipment. The ESD protective symbol should also be used on items designed to replace static generative materials. Examples of these items are ESD protective workstation equipment, trash can liners, and chairs. The item is to be ESD protective or non-static generative by design.

11.5 ESD Symbol References

EOS/ESD-S8.1-1993,[15] *EOS/ESD Association Standard for Protection of Electrostatic Discharge Susceptible Items, Symbols-ESD Awareness.*

EN10015/1-1991,[16] *Protection of Electrostatic Sensitive Devices, Part General Requirements.*

IEC Publication 417-1975,[17] *Graphical Symbols for Use On Equipment.*

RS-471-1980,[18] *Symbol and Label for Electrostatic Sensitive Devices.*

12. Tables

Table 12-1. Triboelectric Series

Asbestos	Acquires a more
Acetate	positive charge
Glass	↓
Human Hair	
Nylon	
Wool	
Fur	
Lead	
Silk	
Aluminum	
Paper	
Polyurethane	
Cotton	
Wood	
Steel	
Sealing Wax	
Hard Rubber	
Acetate Fiber	
Mylar	
Epoxy Glass	
Nickel, Copper, Silver	
401 Epoxy Resist	
UV Resist	
Brass, Stainless Steel	
Synthetic Rubber	
Acrylic	
Polystyrene Foam	
Polyurethane Foam	
Saran	
Polyester	
Polyethylene	
PVC (vinyl)	
KEL F	
Teflon	↓
Viton	Acquires a more
Silicone Rubber	negative charge

Table 12-2. Typical Susceptibility Ranges of Various Unprotected Devices Subjected to Electrostatic Discharge

DEVICE TYPE	RANGE OF ESD SUSCEPTIBILITY (VOLTS)
VMOS	30 to 1,800
MOSFET	100 to 200
GaAsFET	100 to 300
EPROM	100 to 2,500
JFET	140 to7,000
CMOS	250 to 3,000
Schottky Diodes, TTL	300 to 2,500
Bipolar Transistors	380 to 7,000
ECL (for Hybrid Use, PC Board Level)	500 to 1,500
Film Resistors	300 to 3,000
Schottky TTL	1,000 to 2,500
SCR	680 to 1,000

References

Ref.1 Main Text

1. TR-NWT-000870, Electrostatic Discharge Control in the Manufacture of Telecommunications Equipment (a module of RQGR, FR-796), Issue 1 (Bellcore, February 1991).
2. SR-3700, *Economic Impact of Humidifying Telecommunications Central Offices: The Humidity/ESD Study*, Issue 1 (Bellcore, September 1995).
3. GR-1422-CORE, *Generic Requirements for ESD-Controlling Wrist-Straps,* Issue 1, (Bellcore, July 1994).
4. GR-1418-CORE, *Generic Requirements for Wrist-Strap Testers,* Issue 1 (Bellcore, July 1994).
5. GR-1421-CORE, *Generic Requirements for ESD-Protective Circuit Pack Containers,* Issue 2 (Bellcore, June 1995).
6. SR-3400, *Economic Impact of Increasing the Operating Temperature Range Within the Telecommunications Central Offices*, Issue 1 (Bellcore, November 1994).
7. GR-1424-CORE, *Generic Requirements for ESD-Protective Floor Covering,* Issue 1 (Bellcore, February 1995).
8. GR-1423-CORE, *Generic Requirements for ESD-Protective Floor Finishes,* Issue 1 (Bellcore, December 1994).
9. BR 781-810-885, *Ventilation of Central Office Buildings*, Issue 1 (Bellcore, July 1991).
10. GR-1419-CORE, *Generic Requirements for ESD-protective Workstations,* Issue 1 (Bellcore, December 1995).
11. SR-2759, *A View of Package, Palletization and Marking Requirements,* Issue 3 (Bellcore, January 1995).
12. ESD ADV53.1-1995, ESD Association Advisory For the Protection of Electrostatic Discharge Sensitive Items-ESD Protective Workstations.
13. ANSI EOS/ESD-S4.1-1990, Standard for Protection of Electrostatic Discharge Susceptible Items-Work Surfaces-Resistive Characterization.
14. BR 201-021-001, *Heat Stress Test, Description and Methods, Stored Program Control Systems (SPCS)*, Issue 2 (Bellcore, January 1986).
15. EOS/ESD S8.1-1993, *Standard for Protection of Electrostatic Discharge Susceptible Items- ESD awareness Symbols.*

16. EN100115/1-1991, *Protection of Electrostatic Sensitive Devices, Part General Requirements.*

17. IEC Publication 417-1975, *Graphical Symbols for Use On Equipment.*

18. RS-471-1980, *Symbol and Label for Electrostatic Sensitive Devices.*

Ref.2 Glossary References

ANSI EOS/ESD S6.1-1991, *Standard for Protection of Electrostatic Discharge Susceptible Items-Grounding-Recommended Practice.*

EOS/ESD-S3.1-1991. ANSI EOS/ESD S3.1-1991, *Standard for Protection of Electrostatic Discharge Susceptible Items-Ionization.*

EOS/ESD-S5.2-1994.

ANSI EOS/ESD-S5.1-1993, *Standard for Electrostatic Discharge (ESD) -Sensitivity Testing-Human Body Model (HBM) - Component Level.*

ANSI T1.313

ESD S11.11-1993, *Standard for Protection of Electrostatic Discharge Susceptible Items- Surface Resistance Measurement of Static Dissipative Planar Materials.*

Note

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Bibliography

BSP 802-001-196, *Protective Grounding Systems-General Grounding Requirement for Data Processing Equipment Installation*, Issue 1, June 1983.

BR 876-320-100, *Electrical Protection for Headset-User Positions*, Issue 1 (Bellcore, December 1993).

GR-314-CORE, *Generic Requirements for Telephone Headsets at Operator Consoles*, Issue 1 (Bellcore, October 1994).

GR-1089-CORE, *Electromagnetic Compatibility and Electrical Safety - Generic Criteria for Network Telecommunications Equipment*, Issue 1 (Bellcore, November 1994).

GR-63-CORE, *Network Equipment-Building System (NEBS): Generic Equipment Requirements*, (a module of LSSGR, FR-64; TSGR, FR-440; and NEBS FR, FR-2063), Issue 1 (Bellcore, October 1995).

EOS/ESD-S1.0-1987, *EOS/ESD Standard No. 1 Standard for Protection of Electrostatic Discharge Susceptible Items: Personal Grounding Wrist-Straps.*

ANSI EOS/ESD S3.2-1995, *Standard for Protection of Electrostatic Discharge Susceptible Items-Selection and Acceptance of Air Ionizers.*

ESD S7.1-1991, *Standard for Protection of Electrostatic Discharge Susceptible Items-Floor Materials-resistive characterization of materials.*

ESD S9.1-1995, *Standard for Protection of Electrostatic Discharge Susceptible Items-Footwear-Resistive Characterization (not to include heel and toe grounders).*

ESD S11.31-1994, *Standard for Evaluating the Performance of Electrostatic Discharge Shielding Materials: Bags.*

ESD ADV-2.0-1994 ESD *Association Advisory for Protection and Sensitivity Testing of Electrostatic Discharge Susceptible Items - Handbook*

ESD-ADV1.0-1994 ESD *Association Advisory for Electrostatic Discharge Terminology - Glossary*

Unger, B.A., *Circuit Pack Failure, TE&M*, 50, 1993.

Zelluka, R.J., *Tracking Results of an ESD Control Program within a Telecommunications Service*, EOS/ESD Symposium Proceedings, pp36-41, 1989.

EIA Standard EIA-625, *Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices*, October 1994.

EIA Standard EIA-541, *Packaging Material Standards for ESD Sensitive Items*, June 1988.

MIL-W-87893A, 29 July 1994, *Workstation Electrostatic Discharge (ESD) Control*

MIL-STD-1686A, *Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric)*

Glossary

Definition of Terms

Antistatic — Usually refers to the property of a material that inhibits triboelectric charging. Note: A materials antistatic characteristic is not necessarily correlatable with its resistivity or resistance. Although this term "Antistatic" and the term "Astatic" still appear in the literature, both these terms were replaced by the new term **"low charging"** in April 1996 by the International Electrotechnical Commission (IEC).

Bond Or Bonding — The permanent joining of metallic parts to form an electrically conductive path that will assure electrical continuity and the capacity to safely conduct any current likely to be imposed. (from ANSI EOS/ESD-S6.1-1991).

Bus Bar — A metal strip or bar to which several conductors may be bonded. (from ANSI EOS/ESD-S6.1-1991)

Charge Decay — The decrease and/or neutralization of a net electrostatic charge. (from ANSI EOS/ESD-S3.1-1991)

Charged Device Model — A specified circuit characterizing an electrostatic discharge which results when a device isolated from ground is first charged and then subsequently grounded.

Circuit Card Assembly — An assembled printed circuit board with components; in telecommunications systems, this typically refers to a plug-in-board that has a modular function (same as printed board assembly or circuit pack).

Circuit Pack — (See Circuit Card Assemblies)

Common Point Ground (CPG) — (1) A grounded device where two or more conductors are bonded. (2) A system or method of connecting two or more grounding connectors to the same electrical potential. (from ANSI EOS/ESD-S6.1-1991 See also (PGP).

Component — An item such as a resistor, diode, transistor, integrated circuit and hybrid. (from ESD-S5.2-1994).

Conductive Material — A material that has a surface resistivity less than 1×10^5 ohms/square or a volume resistivity less than 1×10^4 ohm-cm.

CRT (CRT Monitor) — See VDT.

Electric Charge — An absence or excess of electrons.

Electrostatic Charge — Electric charge at rest.

Electrostatic Discharge (ESD) — The rapid, spontaneous transfer of electrostatic charge induced by a high electrostatic field. Note: Usually, the charge flows through

a spark between the two bodies at different electrostatic potentials as they approach one another. Details of such process, such as rate of charge transfer, are described in specific electrostatic discharge models.

Electrostatic Discharge Susceptibility (sensitivity) (ESDS) — The propensity to be damaged by electrostatic discharge.

Electrostatic Field — An attractive or repulsive force in space due to the presence of electric charge.

Electrostatic Potential — The voltage difference between a point and an agreed-upon reference.

Electrostatic Shield — A barrier or enclosure that limits the penetration of an electrostatic field.

Equipment Ground — (1) The ground point at which the equipment grounding conductor is bonded to any piece of equipment, at the equipment end of the conductor. (2) The third wire (green) terminal of a receptacle. (3) The entire low impedance path form a piece of electrical equipment to a hard ground electrode. (from ANSO EOS/ ESD-S6.1-1991)

Field Induced Charging — A charging method using electrostatic induction.

Ground — (1) A conducting connection, whether intentional or accidental between an electrical circuit or equipment and the earth, or some conducting body that serves in place of earth. (2) The position or portion of an electrical circuit at zero potential with respect to earth. (from ANSI EOS/ESD-S6.1-1991)

Grounded — Connected to earth or some other conducting body that serves in place of the earth. (from ANSI EOS/ESD -S6.1-1991).

Hard Ground — A connection to ground through a wire or other conductor that has very little or nearly no resistance (impedance) to ground. (from ANSI EOS/ESD-S6.1-1991)

Human Body Model — An electrostatic discharge circuit that meets the set model values by conforming to the waveform criteria specified in ANSI EOS/ESD-S5.1-1993, the electrostatic discharge from a human being. Approximates the ESD from the fingertip of typical human being.

Inductive Charging — The transfer of an electric charge to an object when it is momentarily contacted to ground in the presence of an electric field.

Insulating Material — A material having a surface resistivity of at least 1×10^{12} ohms/ square of 1×10^{11} ohm-cm volume resistivity.

Ionization — The process by which a neutral atom or molecule acquires a positive or negative charge.

Ionizer — A device design to generate positive and/or negative air ions.

Machine Model — An electrostatic discharge simulation test based on a discharge network consisting of a charged 200 picofarad capacitor and (nominally) zero ohms of series resistance. Actual series resistance and inductance are specified in terms of the current waveform through a shorting wire. The simulation test approximates the electrostatic discharge from a machine.

Plug-in — (See circuit card assembly).

Principal Ground Point — A point within a structure that provides a means to join conductors requiring an earth reference to grounding electrodes. This point may be a separate busbar located in the structure near the entrance of the grounding electrode conductor (s), or it may be a point on a grounding electrode. In a central office, the PGP is reference point 0 (see ANSI T1.313).

Shielding — See static shielding.

Static Dissipative — A property of a material having a surface resistivity of a least 1 x 10^5 ohms/square or less that 1 x 10^{12} ohms/square surface resistivity or 1 x 10^{11} ohm-cm volume resistivity.

Static Generator — Any material which when contacted or rubbed with itself or a different material accumulates sufficient electrostatic charge to be an ESD hazard to electronic components or assemblies. See triboelectric series.

Static Shielding — An electrostatic shield or barrier that limits the penetration of an electric field.

Surface Resistance — The ratio of dc voltage to the current flowing between two electrodes of specified configuration that contact the same side of the material (from ANSI EOS/ESD-S11.11-1993).

Surface Resistivity(ρ_s) — For electric current flowing across a surface, the ratio of dc voltage drop per unit length to the surface current per unit width. In effect, the surface resistivity is the resistance between two opposite sides of a square and is independent of the size of the square or its dimensional units. Surface resistivity is expressed in ohms/square. When using a concentric ring fixture, resistivity is calculated using the following expression, where D1=the outside diameter of the inner electrode, D2= the inside diameter of the outer electrode, and R=is measured in ohms (from ANSI EOS/ESD-S11.11-1993).

$$\rho_S = \left[\frac{2\pi}{\ln((D2)/(D1))}\right]R$$

System — A combination of complete assemblies, components, parts, and accessories

connected to perform a specific operation function.

Triboelectric Charging — The acquisition of charge on a material contact or friction with another surface of dissimilar material.

Triboelectric Series — A list of materials arranged so that one can become positively charged when separated from one farther down the list, or negatively charged when separated from one farther up the list.

> **NOTE —** The series' main utility is to indicate likely resultant charge polarities after triboelectric generation. However, this series is derived from specially prepared and cleaned materials tested in very controlled conditions. In everyday circumstances, materials reasonably close to one another in the series can produce charge polarities opposite to that expected. This series is only a guide.

Topical Anistat — An anistat that is applied to the surface of a material for the purpose of making the surface static dissipative or low charging (reduce triboelectric charging). This method of minimizing charge generation is not recommended, and is not permanent, especially in low humidity conditions.

VDT (Video Display Tube) — Synonymous with CRT (Cathode Ray Tube), or CRT Monitor. A device used to display images, typically from broadcast television or a computer.

Volume Resistivity(ρ_v) — The ratio of the dc voltage per unit thickness to the amount of current per unit area passing through a material. Volume resistivity is given in ohm-centimeters.

Workstation — A work area which consists of a tabletop work surface, shelves, storage facilities, powered and/or not powered equipment, assemblies, black boxes, or systems.

Worksurface Groundable Point — A point on the work surface that is intended to accommodate an electrical connection from the work surface to an appropriate electrical ground (from ANSI EOS/ESD-S4.1-1990).

Zap — (colloquial term) See Electrostatic Discharge.

Acronyms

AATCC — American Association of Textile Chemists and Colorists

ASHRAE — American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

ASTM — American Society for Testing Methods

CEV — Controlled Environment Vault

CO — Central Offices

EIA — Electronic Industries Association

EMI — Electromagnetic Interference

EOS/ESD — Electrical Overstress/Electrostatic Discharge

ESD — Electrostatic Discharge

GR — Generic Requirement

IEC — International Electrotechnical Commission

PICS — Plug-In Inventory Control System