NATO STANDARD PACKAGING FOR MATERIEL SUSCEPTIBLE TO DAMAGE BY ELECTROSTATIC DISCHARGE

AEPP 2
(Edition 1)

(March 2007)

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(Edition 1)

NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDIZATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

22 March 2007

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2. AEPP-2 is effective upon receipt.

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Major General, POL (A)
Director, NSA

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RECORD OF CHANGES

Change Date	Date Entered	Effective Date	By Whom Entered

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1. GENERAL

1.1. INTRODUCTION

1. Modern technology has produced devices that are susceptible to permanent damage due to the discharge of electrostatic potentials of the order that would be encountered in routine handling. They have extensive use throughout the services and industry.

2. The construction of devices employing metal oxide semiconductor (MOS) technologies results in very thin dielectric layers of material with breakdown voltage at present as low as 20 volts. Protective circuitry is generally incorporated at the inputs and outputs of these devices; however, this factor does not necessarily protect the device from electrostatic discharges in the surrounding environment.

3. Static electricity is generated in many everyday ways; it can result from an operator moving around on a chair, brushing against a wall or bench, or simply walking across the floor. Devices handed from one person to another or being wrapped or unwrapped can be subjected to electrostatic discharge (ESD). The assembly area may itself produce electrostatic potentials; for example, air conditioning systems and the spraying of synthetic materials (cleaning liquids, etc.) may result in electrostatic potentials being generated. This electrostatic charge is not generally noticed by the operator, but its transfer can nevertheless result in the destruction of the device or degradation of its performance.

4. Materials which are prime generators of electrostatic potentials include common plastics (i.e. polyethylene, vinyl plastics, foam, polyurethane), synthetic textiles, Fiberglas, glass, rubber, and other commonly used materials. Damaging electrostatic potential levels are commonly generated by sliding, rubbing, and separating these materials by industrial processes and personnel movement.

1.2. SCOPE

1. This publication provides requirements and procedures that, if followed, will minimize the risk of ESD damage to static-sensitive devices; it also emphasizes the need for all persons concerned with the handling of these devices to be fully aware of the problems involved. Details of identification requirements, including a caution symbol, have been included for use on related documentation, in storage facilities, and for directly associated material. General requirements and procedures contained herein are applicable to personnel engaged in packaging development or preparation for receiving, shipment, and storage. Additional requirements shall apply for areas with exposed conductors at potentials $>$ 2.5kVa.c. or 2.5kVd.c.

2. Although this publication does not include all requirements for personal safety, attention is drawn to the need for all concerned to comply with relevant local statutory requirements regarding the health and safety of all persons in all places of work, including those covered by this publication.

3. This publication does not apply to static-sensitive explosive devices. Use of this document or the procedures defined herein do not apply to facilities where ordnance, flammables, or explosives are handled or stored.

1.3. APPLICABLE DOCUMENTS

AAP-23	NATO Glossary of Packaging Terms and Definitions
AEPP-3	NATO Standard Packaging Test Procedures
IEC 364-6-61	Electrical Installations of Buildings – Part 6: Verification Chapter 61: Initial
IEC 61340-5-1	Protection of Electronic Devices From Electrostatic Phenomena Part 5-1: General Requirements
STANAG 4272	NATO Standard Methods of Preservation
STANAG 4280	NATO Levels of Packaging
STANAG 4281	NATO Standard Marking for Shipment and Storage
STANAG 4434	NATO Standard Packaging for Materiel Susceptible to Damage by Electrostatic Discharge - AEPP-2.

2. DEFINITIONS

2.1. GENERAL

1. The terms used throughout this publication and their interpretation shall be in accordance with the following definitions. Other relevant terms are defined in AAP-23.

2.2. TERMS

1. **ANTISTATIC (low charging) PROPERTY**. Refers to the prevention of triboelectric charge generation. Antistatic (low charging) materials minimize the generation of static charges. (NOTE: The International Electrotechnical Commission (IEC) feels that the terms astatic and antistatic should be avoided due to the different existing meanings, hence the term low charging is used in IEC publication 61340-5-1.)

2. **CONFORMAL COATINGS**. Sprayed liquids or solid materials applied directly to printed circuit boards (PCB) or electronic components during final manufacture. Once hardened, they provide physical, electrical, and environmental protection. Conformal coatings are organic compounds like epoxy resin with high isolating properties and smooth surfaces.

3. **DEVICE**. An individual part, separate component, integrated circuit, or electronic assembly, such as a microcircuit, semiconductor, or electronic "black box".

4. **ELECTROSTATIC CONDUCTIVE**. Packaging with a surface resistivity $\geq 10^3$ Ω/sq. and $< 10^6$ Ω/sq. or a thickness dependant volume resistivity of $\geq 0.1\Omega$ m per mm of material thickness and $< 10^9$ m per mm of material thickness. Surface resistivity applies to both surface and volume conductive materials and has the value of Ω/sq. The physical SI unit is Ω. The appendage/sq. has been added only to emphasize that the value of the surface resitivity refers to one square.

5. **ELECTROSTATIC DISCHARGE (ESD)**. A transfer of electrostatic charge between two bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

6. **ELECTROSTATIC DISCHARGE SENSITIVE (ESDS)**. The relative tendency of a device's performance to be affected or damaged by an ESD event.

7. **ELECTROSTATIC DISSIPATIVE**. Material with a surface resistivity $\geq 10^6$ Ω/sq. and $< 10^{12}$ Ω/sq. or a thickness dependant volume resistivity of $\geq 10^3$ Ω m per mm of material thickness and $< 10^9$ Ω m per mm of material thickness.

8. **ELECTROSTATIC FIELD**. A voltage gradient between an electrostatically charged surface and another surface of a different electrostatic potential.

9. **ELECTROSTATIC DISCHARGE SHIELDING MATERIAL**. A barrier or enclosure of multilayer material in which the surface layer has a surface resistivity less

than 10^4 Ω/sq. or a thickness dependant volume resistivity of less than 10Ω m per mm of material thickness, that limits the passage of current and attenuates with the energy resulting from an electrostatic discharge such that the maximum energy from 1000 volts of human body model discharge is ≤ 50 nJ.

10. **ESD-FIELD SERVICE KIT**. A portable ESD workstation kit used for handling ESDS items in situations when other ESD control workstations are not available or feasible for use.

11. **ESD PROTECTED AREA (EPA)**. An area in which ESDS items can be handled that is constructed and equipped with the necessary ESD-protective materials, static control equipment, and procedures required to limit ESD voltages below the sensitivity level of ESDS devices handled therein.

12. **ESD-PROTECTIVE WORKSTATION**. A space located within an ESD-protective area that is specifically dedicated to single or related tasks and contains the workbench, equipment, and materials to handle and package ESDS devices.

13. **ESD-PROTECTIVE MATERIAL**. Material with one or more of the following properties: limits the generation of electrostatic charge; dissipates electrostatic charge; or provides shielding from electrostatic fields. For the purpose of this publication, ESD-protective materials are classified as static or antistatic (low charging) dissipative.

14. **ESD-PROTECTIVE PACKAGING**. Enclosing an ESDS device in ESD-protective materials to minimize the possibility of ESD damage.

15. **GROUND**. The uniform potential established in the work area which ensures that the potential of the device and of everything with which it is likely to come into contact is the same. A mass such as earth, a ship, or vehicle hull capable of supplying or accepting an electrical charge.

16. **HANDLED/HANDLING**. Actions in which devices are hand manipulated or machine processed during actions such as inspecting, assembling, processing, testing, reworking, transporting, wrapping, packing, marking, labeling, etc.

17. **INSULATIVE MATERIAL**. Material with a surface resistivity ≥ 10^{12} Ω/sq. or a thickness dependant volume resistivity of ≥ 10^9 Ω m per mm of material thickness. Insulative materials are not classified as ESD-protective materials.

18. **INTIMATE PACKAGING MATERIAL**. Materials which make direct contact with a bare ESDS device.

19. **LOW CHARGING**. Packaging that exhibits properties which minimize any charge generation. (NOTE: The International Electrotechnical Commission (IEC) feels that the terms astatic and antistatic should be avoided due to the different existing meanings, hence the term low charging is used in IEC publication 61340-5-1.)

20. **PROXIMITY PACKAGING MATERIAL**. Material not making contact with a bare ESDS device but which is used to enclose one or more intimate packaging material wrapped devices.

21. **SECONDARY PACKAGING MATERIAL**. Material used primarily to give additional physical protection on the outside of a proximity package.

22. **SURFACE RESISTIVITY** (ρ_s). 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 the direction of current flow in the material. (NOTE: Surface resistivity of a material is numerically equal to the surface resistance between two electrodes forming opposite sides of the square. The size of the square is immaterial. Surface resistivity applies to both surface and volume conductive materials and has the value of Ω/sq. The physical SI unit is Ω. The appendage/sq. has been added only to emphasize that the value of the surface resitivity refers to one square).

23. **TRIBO-ELECTRIC EFFECT**. The electrical charging process in which charge is generated by the contact and separation of two surfaces which may be solid, liquid or particulate-carrying gases. (Example is the generation of static electricity caused by rubbing, contacting, or separating of two surfaces.)

24. **UNIT PACK**. The first tie, wrap, or container applied to a single item or a quantity thereof or to a group of items of a single stock number, preserved or unpreserved, which constitutes a complete or identifiable package.

25. **VOLUME RESISTIVITY** (ρ_v). An inverse measure of the conductivity of a material and equal to the ratio of the potential gradient to the current density, where the potential gradient is measured in the direction of the current flow in the material. (NOTE: In the metric system, volume resistivity of an electrical conducting (more or less isolating) material in Ω cm (or Ω m) is numerically equal to the volume resistance in Ω between opposite faces of a cm or m cube of the material. Volume resistivity in Ω mm has a value of 10 times the value in Ω cm (or 1000 times the value in Ω m.)).

26. **WATER-VAPOURPROOF MATERIAL**. A barrier material offering a high resistance to the passage of water vapour. The water-vapour transmission rate (WVTR) shall not exceed 1g/m^2 in 24 hours when measured at a temperature of 38^o C with a relative humidity of 90 percent.

3. REQUIREMENTS

3.1. IDENTIFYING ESDS DEVICES

1. Due to the large number of electronic devices presently used by the military and the methods needed to accomplish the task, identifying devices that are ESDS is essential. Electrical and electronic devices, that have been determined to be ESDS, include microelectronic discrete and integrated semiconductors; thick and thin film resistors, chips, and hybrid devices; and piezoelectric crystals. Subassemblies, assemblies, and equipment containing these devices are also ESDS. ESDS devices are categorized as follows:

a. All printed circuit boards (cards), wiring boards, and modules or assemblies with mounted ESDS components and designated subassemblies (ESDS components) of NATO Supply Classes:

(1) 1430 - Guided Missile Remote Control Systems

(2) 4935 - Guided Missile Maintenance Repair and Check-out Specialized Equipment

(3) 5998 - Electrical and Electronic Assemblies; Boards, Cards, Associated Hardware

(4) 5999 - Miscellaneous Electrical and Electronic Components

b. All devices within NATO supply classes:

(1) 5905 - Resistors, precision or thin film:

(a) Fixed, Film
(b) Fixed, Film, Chip
(c) Network, Fixed, Film

(2) 5955 - Oscillators and Piezoelectric Crystals

(3) 5961 - Semiconductor Devices:

(a) Hybrid Semiconductors
(b) Metal Oxide Semiconductors Field Effect Transistors (MOSFET)
(c) Junction Field Effect Transistors (JFET)
(d) Microwave Diodes
(e) Silicon-Controlled Rectifiers (SCRs)
(f) Small Signal Schotty Diodes
(g) Semiconductor Devices (operating at a frequency above one gigahertz)

(4) 5962 - Microcircuits

(5) 5963 - Electronic Modules

(6) 5980 - Optoelectronic Devices (LEDs, Phototransistors, Opto Couplers)

(7) 7042 - Mini and Micro Computer Control Devices

(8) Surface Acoustic Wave (SAW) Devices

c. Any complete system, "Black Box", Line Replaceable Unit (LRU), Shop Replaceable Unit (SRU), Electronic test or repair equipment console/device or component containing the assemblies or parts mentioned above shall be considered ESDS.

2. ESD susceptibility is suspended when the devices are correctly packaged or the level of assembly is such that a complete electrostatic shield exists around the device or until which time it can be shown by testing that the ESDS device is protected from electrostatic potentials above 15kV.

3.2. PACKAGING GUIDELINES

1. Devices identified as ESDS will be protected from production to final disposal.

2. Unprotected ESDS devices shall be handled only at an ESD-protective workstation (safe handling area) by trained personnel.

3. The protection provided by the packaging of ESDS devices precludes the application of NATO Method 6 of STANAG 4272, NATO Standard Method of Preservation. Intimate protection against the effects of the environment will be gained through other treatments that do not introduce an additional hazard, such as uncontrolled or excessively low humidity levels (20% r.h.), or a source of contamination.

4. The selection of electrostatic dissipative and conductive materials used as part of the unit pack will conform to the performance criteria specified herein. Regardless of the material form, they will offer the dissipative and conductive property without affecting other material characteristics, introducing a corrosive environment, or losing this protection during long-term storage.

5. In all cases, the intimate packaging material(s) surface has to be electrostatic dissipative. Such material may be in the form of a homogeneous single film of cushion thickness or a multilayered structure either as a flat film or cushioning pad, as in a pouch configuration.

6. Proximity shielding will be required to protect against the effects of electrostatic discharge or electrostatic fields. This protection is normally available in materials through the use of conductive layers attained by carbon loading, metalization, or other manufacturing techniques. When applied, whether as composite structure, pouches, or laminates, conductive (inside) surfaces of the electrostatic and electromagnetic shielding barrier material shall not be placed against bare devices.

7. Selection of the appropriate packaging material(s) will be based on the nature of the device and prescribed packaging data, if available. Where a possible projection hazard may exist, due to penetration through the electrostatic dissipative surface into the conductive portion of the material, additional wraps or a different form of ESD-protective material will be specified.

8. Whenever an ESDS device, assembly, or system is transported between work areas or workstations, prior to being packaged, the device shall be contained in

electrostatic-conductive or electro-static dissipative tote boxes, trays, bags, fast packs with bonded polyurethane, low charging, flexible foam cushioning pads, etc. to provide protection from the contamination and mechanical damage as well as electrostatic protection. (NOTE: At no time shall an ESDS device be left unprotected.)

9. When an unprotected ESDS device is dropped, it requires functional testing (serviceability tests), prior to being packaged.

10. New unused ESD-protective packaging materials or materials designed to be reusable will be used to form the unit pack.

11. Removal of devices from interim protective packaging and subsequent handling shall be accomplished only within a protected area. (NOTE: Where tape is acting as a seal, it shall be cut to open the bag, box, or container and not stripped away). Unnecessary repackaging of an ESDS device constitutes excess handling and shall be avoided wherever possible.

12. Whenever an ESDS device is to be exposed, workstation(s) have to be cleared of any materials which are not ESD-protective to preclude the possible damage of items either through direct contact with such sources from electrostatic charge build-up or as the result of ESD produced within an electrostatic field created by these materials.

13. It is essential that the handling of ESDS devices be kept to an absolute minimum and then only in an ESD-protective work area by trained personnel.

14. ESD-protective pouches shall be used for technical manuals, drawings, work instructions, etc., within the protective work area.

15. Contractors may propose the use of their ESD safe commercial packaging materials provided they can demonstrate that the packaging will provide equal or better protection than that specified by the cognizant procuring activity.

16. NATO levels of packaging, packaging test procedures, and resistivity, resistance, and measurement test procedures and test equipment are depicted in STANAG 4280, AEPP-3, and Annex D, respectively.

17. The commodity identification and shipping markings shall be in accordance with STANAG 4281, NATO Standard Marking for Shipment and Storage.

3.3. PACKAGING MATERIALS

1. Packaging materials are those materials which cushion, enclose, or protect the ESDS device during handling, transporting, and storage, such as bags, boxes, pouches, tubes, wraps, foams, loose fill,[1] etc.

[1] Loose fill shall not be used in packages shipped to US Army, Navy, or Defence Logistics Agency activities.

a. Materials shall maintain their low charging resistive and shielding properties throughout the packaging material life cycle (during application, storage, transporting, distribution, and up to the point of disposal).

b. Materials that are prime generators of electrostatic charges, (untreated plastic films, foams, synthetic fibers, self adhesive tapes, etc.), shall not be used as intimate or proximity packaging materials and shall be excluded from the ESD-protective work area.

c. Materials or surfaces which are in intimate contact with ESDS devices shall be either low charging and electrostatic conductive or low-charging and electrostatic dissipative materials (for powered ESDS only low-charging and electrostatic dissipative materials with a surface resistivity $< 10^8$ Ω/sq. shall be used).

d. Materials used for proximity packaging, which surround or enclose an ESDS device, shall be procured with a charge decay characteristic of 10 percent of the initial value (maximum 1,000 V) in < 2.0 seconds. Use of outer surfaces which are "hard ground", i.e., $< 10^3$ Ω/sq. surface resistance is allowed when approved by the ESD coordinator.

e. Materials used as secondary packaging are primarily to give additional physical protection on the outside of a proximity package, i.e., provide physical protection for proximity packaging.

2. The Resistivity Chart for Packaging Materials, Table 1, lists general guidance for the selection of intimate, proximity, and secondary packaging materials (by surface or volume resistivity).

3. ESD characteristics of packaging materials and typical products (by surface resistivity range) are listed in Table 2.

Table 1 - RESISTIVITY CHART FOR PACKAGING MATERIALS
Surface Resistivity in Ω/sq. (ohm per square)
Thickness Dependent Volume Resistivity in Ω/cm (ohm X cm) per mm of Material Thickness (shown in brackets)

Intimate packaging materials Note 1		Proximity packaging materials Note 1			Secondary packaging material
Voltage sensitivity (VS) in kV Note 2	Unpowered ESDS Device	Powered ESDS Device	Within ESD EPA	Uncontrolled Conditions	Secondary packaging material shall have no special requirements, provided that:
VS < 4	10^3 to 10^{12} (10^2 to 10^{11}) Note 3	10^8 to 10^{12} (10^7 to 10^{11}) Note 3	Electrostatic Shielding 10^3 to 10^6	Electrostatic Shielding	a) ESDS devices remain in their proximity packaging when placed in or taken out of (and) b) The secondary packaging is not brought into an ESD work area. If either of the above conditions is not satisfied, then secondary packaging material shall be used.
4 ≤ VS < 15			10^3 to 10^{12} (10^2 to 10^{11}) Note 3	10^3 to 10^6 (10^2 to 10^5)	
15 ≤VS					

Notes:

1. A single static shielding bag with an electrostatic dissipative inner surface may be used as both the intimate and proximity packaging, provided that the outer surfaces are not capable of holding an electrostatic charge when grounded and a box is provided for physical protection which will not generate an electrostatic charge.
2. Unless specified by the ESDS device manufacturer, requirements for voltage sensitivity of <4 kV shall be used.
3. Where surface resistivity is $>10^{10}$ Ω/sq. or the surface dependent volume resistivity of $>10^{9}$ Ω cm per mm of material thickness is used then the material shall be procured with a static decay characteristic of 1 kV to 50 V in under 2s.

Remarks:

1. These are minimum requirements and improved levels may be used if required. In particular, packaging appropriate to more sensitive ESDS devices may be used.
2. Test procedures are included in Annex D.
3. Surface and volume resistivity measurements shall be taken at (25+/-5) percent relative humidity.
4. Surface resistivity applies to both surface and volume conductive materials and has the value of Ω/sq. The physical SI unit is Ω. The appendage/sq. has been added only to emphasize that the value of the surface resistivity refers to one square.

Table 2 - ESD CHARACTERISTICS OF MATERIALS

Nomenclature	Surface Resistivity Range	TV-pical Products	**Comments and Cautions**
Conductive Material	> 10^3 Ω/sq ≤ 10^6 Ω/sq.	Conductive foam Conductive containers Electrostatic shielding (with dissipative outer material) Metallized bags	Generally acceptable for ESD damage prevention and control
Dissipative (or Electrostatic) Material	> 10^6 Ω/sq. ≤ 10^{12} Ω/sq.	Workbench tops, mats and chairs Some tool handles Some tote boxes Finger cots, gloves and shoes Pouch or bag, plastic, cushioned and uncushioned Container with polyethylene cushioning Foams, polypropylene and polyethylene Wraps and cushions, plastic	Generally acceptable for ESD damage prevention and control
Insulative Material	> 10^{12} Ω/sq.	Teflon, Plexiglass Cellophane tapes Untreated paper products Standard plastic tubes, caps, plugs, tools and sandwich bags Rubber/plastic coats and gloves	Provides little or no ESD protection and shall not be used for ESD damage prevention and control and shall not be present in ESD protected areas.
Shielding Material	< 10^4 Ω/sq.	Electrostatic shielding w/dissipative outer material Trolley carts and wagons Some tote boxes Pouches and bags Cushion wrap Some containers	Generally accepted materials which are capable of attenuating an electrostatic field and electromagnetic radiation.
Low Charging (antistatic) Materials	> 10^{12} Ω/sq. < 10^{14} Ω/sq.	Poly bags Surface cleaners Finger cots Bubble wrap and packing materials Foam, polyurethane	Provides ESD damage prevention and control, when used in combination with conductive and/or dissipative materials.

Remarks**:**

1. Paper, fibreboard, and other natural fibre products are electrostatic dissipative under moderate or high relative humidity conditions. Because of this variability and because they are often processed with corrosive agents, containers made form such materials are generally not acceptable for ESDS device processing or storage, if used alone.
2. Bags, boxes, gloves, and work surfaces manufactured with carbon-filled plastics are usually conductive but may present a contamination hazard if rubbed or abraded; therefore, such materials should be used with caution.
3. Surface resistivity applies to both surface and volume conductive materials and has the value of Ω/sq. The physical SI unit is Ω. The appendage/sq. has been added only to emphasize that the value of the surface resistivity refers to one square.
4. Protective packaging materials for ESDS devices, by description, are listed in Annex A. The list is not considered all-inclusive because of the rapid technological changes which affect materials available from supply sources.

3.4. PACKAGING PROCEDURES

1. **Unpowered and powered ESDS devices**.

   a. Unpowered devices with leads may be mounted on electrostatic conductive foam to "short out" the pins.

   b. Shelf-powered devices which may contain batteries, charge capacitors, or other energy sources shall be packed with intimate packaging materials with surfaces which are electrostatic dissipative or in a electrostatic protective container specifically designed to avoid contact with individual leads or circuit tracks.

   c. Powered devices shall not be packed in direct contact with surfaces or materials which have a surface resistivity of $< 10^7$ Ω/sq.

2. **Field returns**.

   a. ESDS devices, assemblies, or systems shall be returned conforming to the prescribed packaging requirements.

   b. When new (unused) ESD-protective packaging materials are not available, approved reusable ESD-protective materials may be used for limited packaging of unserviceable field returns.

3.5. PACKAGING METHODS

1. General. The method selected for packaging ESDS devices must provide the requisite ESD protection in accordance with the NATO nations' prescribed packaging requirements. In addition to the method below, other approved packaging methods may be used to satisfy requirements.

2. **Unit pack**[2]

a. **Electrostatic dissipative**.

(1) Wrap the device with transparent/translucent, waterproof, electrostatic protective, static dissipative, barrier material (see table 2 and Annex A) or;

(2) Cushion the device with electrostatic dissipative, flexible, closed cell, noncorrosive, plastic dissipative (may be fire retardant), polyethylene foam sheet cushioning material; hexagonal, electrostatic free, with or without top laminate, light-weight, transparent, flexible, open cell, heat-sealable cushioning material; or low density, resilient, unicellular, closed cell, electrostatic protective, polypropylene foam cushioning material (see table 2 and Annex A) or;

(3) Place the device in a flexible, electrostatic-free, recloseable (zipper type closure), three ply, transparent pouch or a single-ply, heat-sealable, lip closure cushioning pouch fabricated from flexible, transparent, waterproof, electrostatic protective, electrostatic dissipative barrier material (see table 2 and Annex A).

b. **Electrostatic shielde**d.

(1) Place the wrapped/cushioned/bagged device in a heavy duty, water-proof electrostatic bag. The bag may be fabricated from one piece of material folded in half and heat sealed on three sides (see table 2 and Annex A). The bag will be folded over and sealed and a suitable caution label applied.

c. **Antistatic (low charging) Fast Pack**.

(1) ESDS devices (e.g., circuit boards, resistors, semiconductors, microcircuits, etc.) may be packed in reusable boxes as described in Annex A or containers (e.g., plastic, conventional fibreboard, etc.) that provide equivalent protection against electrostatic discharge. Conventional conductive layers normally have a limited lifetime. It is to be assured that the life-time in not smaller than the storage-time.

(2) The container shall be sealed with minimum 60mm wide waterproof packaging tape placed over all seams, corners, and manufacturer's joints.

(3) The container shall be marked on both ends with the words "REUSABLE" and "ANTISTATIC".

[2] Sometimes referred to as intimate packaging.

3. **Intermediate - exterior container**[3]

a. When applicable, the use of intermediate and exterior containers are encouraged.

b. Proximity packaging materials which surround or enclose an ESDS device shall be capable of dissipating electrostatic potentials. Packaging materials may be constructed in a manner to fulfil the requirements of electrostatic shielding bags; or use electrostatic shielding bags; or use separate components such as dissipative foam-lined conductive boxes (see table 1 and 2 and Annex A).

3.6. WARNING LABELS AND MARKINGS

1. **General guidance.**

a. ESDS Basic Symbol (see Figure 1a). All unit packs and intermediate and exterior containers of ESDS devices (or other electronic devices that are alone or are part of assemblies) that are susceptible to damage from an ESD event shall be labelled or marked with the appropriate and specified warning notice. The notice shall include the ESDS basic symbol.

b. ESD Protective Symbol (see Figure 1b). This symbol is a reaching hand in a contrasting triangle surrounded by a bold arc. It 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. It should also be used on items designed to replace static generative materials. Examples of these are ESD protective work station equipment, trash can liners, and chairs. The item is to be ESD protective or non-static generative by design. The symbol shall not be used on ESD susceptible devices or assemblies. The symbol may be a printed, embossed, hot stamped, silk screened or may be incorporated through other mechanisms.

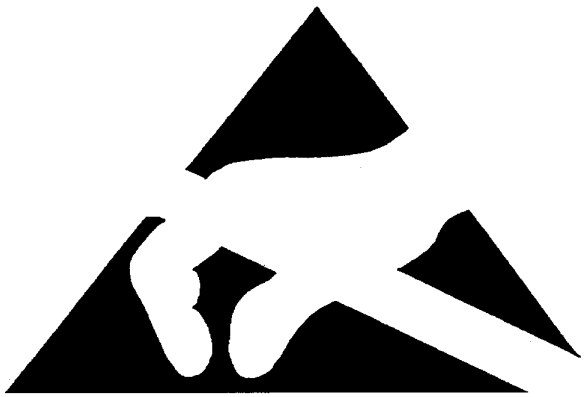

FIGURE 1a. ESDS BASIC SYMBOL

[3] Sometimes referred to as proximity and secondary packaging.

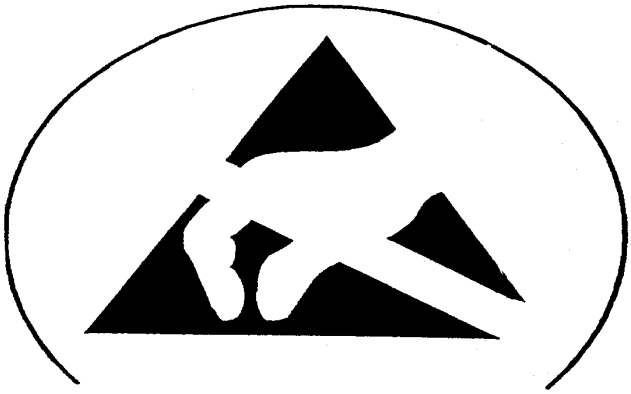

FIGURE 1b. ESD PROTECTIVE SYMBOL

2. **Unit packs.**

a. All unit packs shall be marked with the ESDS devices warning label.

b. The label shall include the ESDS basic symbol (see figure 1), the words "ATTENTION - ELECTROSTATIC DISCHARGE SENSITIVE DEVICES" and the statement "HANDLE ONLY AT ELECTROSTATIC SAFE WORK STATIONS" or similar words such as "ATTENTION - ELECTROSTATIC DISCHARGE SENSITIVE DEVICE" and the statement "TO BE OPENED BY AUTHORIZED PERSONNEL ONLY" (see figure 2). The text may be in the language of the original country. The printing should be in black on a yellow background and the reaching hand may be in yellow on a black triangle with a yellow background.

c. The recommended sizes of the unit label are 50mm long and 20mm high or 85mm long and 35mm high. The size used should be proportionate to the size of the package.

d. The label shall be located adjacent to the identification markings of the contents. Where an electronic assembly or housing contains one or more ESDS device, it shall be labelled such that the warning can be clearly seen before an ESDS device is placed at risk due to contact.

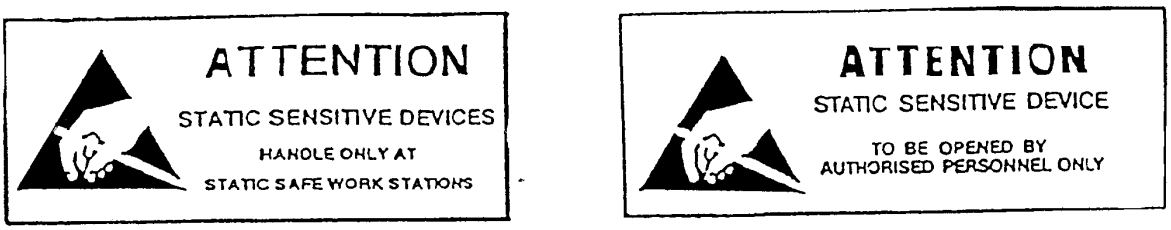

FIGURE 2. Warning label for ESDS devices - unit packs

e. Where space does not permit the use of the ESDS warning label, as a minimum, the ESDS basic symbol (see figure 1a) shall be applied. The

minimum size of the symbol shall be 10 mm measured vertically at the base of the triangle.

f. The marking can take the form of printed tapes, stenciling, or machine printing or stamping. The markings shall be printed in black or the same colour as the identification markings, if other than black.

g. Unit packs used as exterior containers shall be marked with the unit pack warning label.

3. **Intermediate and exterior containers**.

a. Intermediate and exterior containers shall be marked with the ESDS device warning label.

b. The label shall include the ESDS basic symbol (see figure 1) and the words "ATTENTION - OBSERVE PRECAUTIONS FOR HANDLING ELECTROSTATIC DISCHARGE SENSITIVE DEVICES" shall be marked in black on a yellow background. The reaching hand may be in yellow on a black triangle with a yellow background (see figure 3).

FIGURE 3.Warning label for ESDS devices-intermediate and exterior containers

(1) Intermediate container - one warning label, recommended size 50mm by 50mm or 120mm long by 50mm high, shall be placed adjacent to the identification marking of contents.

(2) Exterior container ($< 0.012\ m^3$) - two warning labels, recommended size 50mm by 50mm or 120mm long by 50mm high, shall be placed on each container, with one label placed on the identification-marked side (surface) and one label placed on the opposite side.

(3) Exterior container ($> 0.023\ m^3$) - two warning labels, recommended size 100mm by 100mm or 120mm long by 50mm high, shall be placed on each container, with one label placed on the identification marked side (surface) and one label placed on the opposite side.

c. If the label is temporarily unavailable, intermediate and exterior containers may be marked as prescribed in paragraph 306.3b and 306.3d.

d. The marking can take the form of printed tapes, stenciling, or machine printing or stamping. The markings, 10.5mm measured vertically, shall be printed in black or on the same colour as the identification markings, if other than black.

3.7. ESD ENVIRONMENT

1. ESD Protected area (EPA).

a. A controlled working environment provides the most effective means of preventing damage to unprotected ESDS devices.

b. The work area shall be designed to ensure that ESDS devices can be handled with minimum risk of damage as a result of ESD and shall have defined boundaries.

c. An electrostatic-field strength metre may be required in the work area for measuring and monitoring static charges, and more specifically for identifying unacceptable static charges on incoming devices and packaging materials.

Table 3 - RESISTIVITY AND RESISTANCE GUIDE FOR ESD PROTECTIVE AREA

Item(s)	Surface Resistivity[5] Note 1, 2, 3 & 5	Volume Resistivity Note 1, 2 & 3	Resistance to Ground Note 3
Working surfaces including storage	> 10^4 Ω/sq.	> 10^3 Ω/cm	> 7.5 x 10^5 Ω
racks and floor (required for grounding personnel)	< 10^9 Ω/sq.	< 10^8 Ω/cm	< 10^9 Ω
Floor	> 10^4 Ω/sq.	> 10^3 Ω/cm	> 7.5 x 10^5 Ω
(not required for grounding personnel)	< 10^{12} Ω/sq.	< 10^{11} Ω/cm	< 10^{12} Ω
Trolley carts and wagons	> 10^4 Ω/sq.	> 10^{13} Ω/cm	> 7.5 x 10^5 Ω < 10^9 Ω (frame)
	< 10^9 Ω/sq. (platform only)	< 10^8 Ω/cm (platform only)	< 10^{10} Ω (platform)
Seating	> 10^4 Ω/sq.	> 10^3 Ω/cm	> 7.5 x 10^5 Ω
	< 10^9 Ω/sq.	< 10^8 Ω/cm	< 10^{12} Ω Note 4
Garments	> 7.5 x 10^5 Ω/sq. < 10^{12} Ω/sq.		
Gloves/finger cots	< 10^6 Ω/sq.	< 10^5 Ω/cm	
Wrist strap	< 10^7 Ω/sq.		< 3.5 x 10^7 Ω
Cords			> 9 x 10^5 Ω < 5 x 10^6 Ω (end to end)
Hand to remote end of cord			> 9 x 10^5 Ω < 3.5 x 10^7 Ω
Footwear (required to ground personnel)			< 3.5 x 10^7 Ω

Notes:

1. Surface and volume resistivity measurements shall be taken at (25 +/- 5) percent relative humidity.
2. Depending on the type of material, surface resistivity or volume resistivity figures shall be used.
3. Test procedures are included in Annex D.
4. $< 10^9\Omega$ from seat back and arm pad to at least one foot.
5. Surface resistivity applies to both surface and volume conductive materials and has the value of Ω/sq. The physical SI unit is Ω. The appendage/sq. has been added only to emphasize that the value of the surface resistivity refers to one square

d. The relative humidity should be maintained above 20 percent, as low humidity severely reduces the dissipation effectiveness of materials used in certain types of work surfaces, packaging materials, and clothes. However, high relative humidity (e.g., 70 percent) shall not be used as a prime means of controlling ESD. Excessive humidity can cause problems such as corrosion, possible leakage paths for high voltages, and moisture contamination within equipment.

e. The surface of racking, shelving, carousels, and dispensers which are used to hold unprotected ESDS devices shall meet the requirements of a working surface material as specified in table 3 and shall be grounded.

f. Only approved ESD-protective packaging material or containers shall be used or stowed within the work area.

g. The work area, including boundaries, entrances, and exits shall be clearly identified by specified signs.

h. A summary of requirements for an ESD-protective work area are given in Annex B.

2. **Protective workstation**.

a. The outer perimeter of the workstation area will be identified as a restricted area for trained personnel to handle ESDS devices.

b. A workstation should consist of electrostatic dissipative table(s) or bench surfaces, drawers for components, accessories and packaging pouches, ionizer with monitor, personal wrist straps, heel grounds straps (as required), grounding cords, grounding attachments, conductive floor mats or floor covering, and electrostatic dissipative chairs/stools (see table 3 for surface and volume resistivity). Figure 4 illustrates the typical layout of an ESDS device-protective workstation. Minimum equipment and components are listed in Annex C.

c. An ionizer is a precautionary device that, within its effective area of control, will aid in removing electrostatic potentials from ungrounded conductive and insulative materials.

d. An earth grounding point shall be established on all work surfaces and nonpermanent flooring. A separate earth grounding point is not required for permanent flooring which has a resistance to ground value within limits (see figure 4 and table 3).

e. All working surfaces and floor covering materials, shall be capable of being brought to ground and shall have a surface resistivity $> 10^4\ \Omega$/sq. and $< 10^{12}\ \Omega$/sq. (see figure 4 and table 3).

f. A wrist strap shall consist of a band that fits snugly around the wrist with a quick-release connection and a cord containing a safety resistor to connect the band to an earth-bonding point.

g. The wrist strap shall be made from materials that provide for the inner surface, next to the skin, with a surface resistivity of $< 10^7\ \Omega$/sq. with the intention of making permanent contact with the wrist (see figure 4, table 3 and Annex C).

h. A dedicated earth-bonding point for the wrist strap cord shall be established adjacent to each workstation, such that it is easily accessible without obstructing the work in hand nor presenting a possible hazard in the working environment, or the wrist strap cord may be connected to earth via the work surface conductive element, provided the total resistance to ground is $< 10^7\ \Omega$.

i. The connecting cord shall incorporate a quick release jack or plug and at least one insulated $10^6\ \Omega$ (between $10^5\ \Omega$ and $10^6\ \Omega$ current-limiting resistor at the identified wrist end of the cord, and the total resistance from end to end shall not be $> 5 \times 10^6\ \Omega$ (see table 3). The power rating of this resistor shall be at least 0.25 watt per $10^6\ \Omega$. The complete cord shall withstand a voltage test of 250 volts a.c. or 500 volts d.c. between ends for each $10^6\ \Omega$ for a minimum of 20 seconds. The total resistance from the hand to the remote end of the cord (including the wrist strap and cord) shall be between $10^6\Omega$ and $10^8\Omega$.

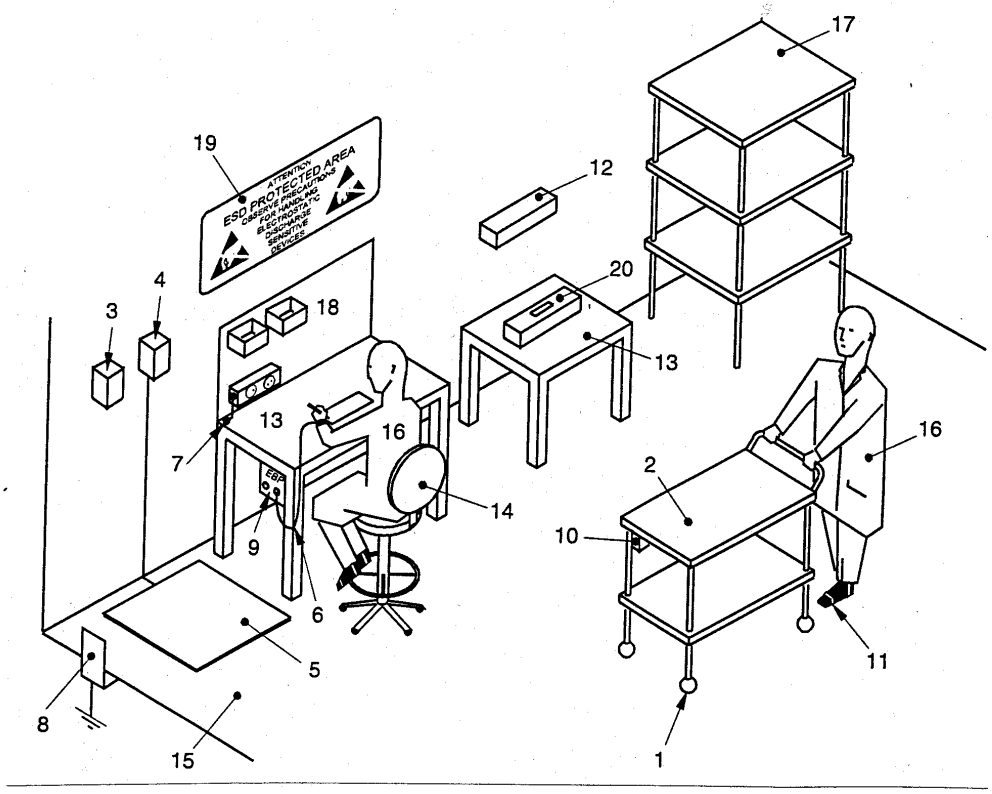

FIGURE 4. Typical packaging workstation layout

1 Groundable wheels
2 Groundable surface
3 Wrist-strap tester, shall be displayed outside the EPA
4 Footwear tester, shall be displayed outside the EPA
5 Footwear tester foot plate
6 Wrist cord and wrist band (wrist strap)
7 EPA ground cord
8 EPA ground
9 Earth bonding point (EBP)
10 Groundable point of trolley
11 ESD protective footwear
12 Ionizer
13 Working surfaces
14 Seating with groundable feet and pads
15 Floor
16 Garments
17 Shelving with grounded surfaces
18 Groundable racking
19 EPA sign
20 Machine

j. Where leg straps, toe and heel grounders, and electrostatic dissipative footwear are used as a prime or only means of grounding personnel, the floor shall be suitable for grounding personnel (see table 3), and shall be within the controlled boundaries of the work area.

k. Coats, jackets, smocks, and overalls shall be designed to completely enclose all outer clothing in the areas of the arms and chest as a minimum. These garments shall be capable of being bonded directly or indirectly to the operator's skin. There shall be electrical continuity $> 7.5 \times 10^5$ and $< 10^{12}$ Ω/sq. between both sleeves and the body of the garment. The material of the garment shall have a surface resistivity on both the outward and inward facing sides $> 7.5 \times 10^5$ and $< 10^{12}$ Ω/sq. and be capable of being grounded.

(NOTE: Due to the redundancy of protection accorded by a work station, special clothing or shoes may not be required). See table 3 for change decay time requirements.

l. All tools intended for use at the workstation shall, as far as is practical, be so constructed that they do not generate or hold an induced electrostatic charge, and any part of the tool which may touch an ESDS device shall be at earth potential.

m. Those tools having insulated handles which generate or hold an electrostatic charge shall be treated with a suitable electrostatic dissipative material, or the handles must be replaced with electrostatic dissipative handles, or the tools must be replaced with tools equipped with electrostatic dissipative handles.

n. Heat-sealing equipment should be located adjacent to the workbench so the wrist strap will remain attached while heat sealing bags.

o. Clean dust and dirt from the tabletop and floormat as often as needed to prevent any accumulation which will insulate ESDS devices and make them ineffective.

3. **Temporary workstation**.

a. The ESD temporary workstation (e.g., a field service kit) provides the required protection where formal workstations are not practical (i.e., remote locations such as shelters and vans).

b. The field service kit is a field expedient and contains only the minimum requirements for ESD control. Their primary use is in support of personnel who handle ESDS devices during which time devices are outside of the prescribed packaging (see Annex C).

c. A field service kit consists of a foldable, flexible electrostatic dissipative work mat with integral wrist straps, grounding cords, and grounding attachment.

d. Proper use of the workstation kit will be dependent upon training, prescribed usage, and the recommended practices in personnel handling of bare ESDS devices.

e. It must be noted that the electrostatic dissipative work mats with accessories are not a substitute for a complete ESD-protective workstation.

3.8. PRECAUTIONS

1. Handle all ESDS items at a electrostatic-safeguarded workstation and transport all ESDS devices in electrostatic protective packages or containers.

2. Adhere to the following precautions when using an ESD-protective workstation:

   a. When protective apparel is worn, it should be frequently checked, especially after cleaning, by scanning personnel with an electrostatic field meter to monitor for damaging ESD voltages.

   b. No more than two wrist strap cords shall be connected to an earth-bonding point. Each wearer at the workstation shall be provided with an earth-bonding point.

   c. Any packaging materials, equipment, or tools that are not electrostatic dissipative, or electrostatic conductive, including non-electrostatic sensitive devices, shall be packed in electrostatic dissipative materials before being taken into an ESD-protective work area. Packaging or unpacking of non-electrostatic dissipative material is to be done at the border of the ESD-protective work area.

   d. Ensure secure attachment of the wrist strap (mandatory) and leg straps (if used) before handling any ESDS device.

   e. Daily monitoring of the wrist strap is essential to ensure that the protective resistor (usually one megohm) is still intact, and the skin resistance to ground is maintained. If the wrist strap resistance is $< 2.5 \times 10^5 \Omega$ or indicates an open circuit, do not use it.

   f. Ensure that ionization is not to be used in an attempt to eliminate the use of either a wrist strap or protective work surfaces and floors.

   g. Ensure that work surfaces are clean, tidy, and free from unnecessary materials.

   h. A visual check shall be made to ensure that all trolleys have a complete earth-bonding system and that all connections are in place.

   i. Avoid the presence of any non-antistatic (non low charging) or insulative material such as styrofoam cups, common plastic or masking tape, common wrapping or barrier materials (e.g., bubble pack, plain poly, etc.), cigarette packs, and synthetic materials (e.g., rayon, orlon, plastics of any type, etc.) in or near the workstation.

   j. Do not perform stretch- or shrink-wrapping operations within the ESD-protective work area.

   k. If more than one ESD-controlled workstation is located in the same area, do not connect the table tops or floormats in series; individually ground each one.

   l. Do not use waxes, polishes, or similar materials on the floormat or tabletop. They may deposit an insulating layer of residue thus reducing or eliminating the effectiveness of the floormat or tabletop. For the same reason, the use of topical antistatic (low charging) spray is not recommended on packaging materials.

m. Ensure that cleaning personnel do not apply silicone type polish to any static dissipative work surfaces, flooring, etc., and hence degrade the performance of same. Only clean water is to be used.

n. Perform continuity checks of all ground wires weekly to ensure that total resistance from top surface to ground should be between $10^6\,\Omega$ and $10^9\,\Omega$.

o. A check shall be made to ensure that the relative humidity (r.h.) conforms to requirements. This shall be checked at the start of every work period and then at suitable intervals.

p. Care should be taken when using large shunts which may cause inducted voltage to occur. The maximum inducted voltage may not exceed 100V.

3.9. TRAINING, QUALITY, and AUDITS

Details on the proper training, prime quality responsibilities, and conducting periodic audits associated with protection of ESDS devices can be found in IEC 61340-5-1.

ANNEX A - PROTECTIVE PACKAGING MATERIALS FOR ESDS DEVICES

DESCRIPTION
Bags, plastic, flexible, single-wall, transparent, waterproof, electrostatic protective, static dissipative with recloseable interlocking type closure:
Bags, sleeves, and tubing, heat sealable, flexible, opaque or transparent plastic: Type I — Heavy duty Class A — Waterproof, electrostatic free Style 2 — Transparent Type I - — Heavy duty Class F - — Water-vaporproof, electrostatic free Style 1 — Opaque
Barrier materials, flexible, electrostatic protective, heat sealable: Type I - Water-vaporproof, electrostatic protective Type II - Transparent, waterproof, static dissipative (plastic) Type III - Transparent, waterproof, electrostatic shielding
Box, fibreboard, shipping, reusable with prefoamed polyurethane, antistatic (low charging), flexible foam:[4] Type II - Triple slide, modified (omit middle tube), corrugated fibreboard, weather resistant Style D - Cushioning, polyurethane foam (type III, class 2, grade A, B, or C)
Cushioning material, lightweight, transparent flexible, open cell, heat-sealable, plastic: Type III - Hexagonal, electrostatic free Style A - Without top laminate Style B - With top laminate
Cushioning material, polyethylene foam: Type VII - Packaging material Class 3 - Special purpose sheets, planks, and shapes Grade B - Static dissipative Grade D - Static dissipative and fire retardant

[4] Commonly referred to as an antistatic (low charging) fast pack.

DESCRIPTION	
Cushioning material, resilient, low density, unicellular (closed cell), polypropylene foam (temperature range from -54º to +71º C):	
Type II -	For electrostatic protective cushioning applications
Pouches, cushioned, flexible, electrostatic-free transparent plastic, reclosable interlocking (zipper-type) closure or heat-sealable lip:	
Type I -	Three-ply; two outer plies, barrier material
Type II -	Single-ply cushioning material

NOTE: Detailed requirements for packaging materials can be found in par. 303.

ANNEX B - PROTECTIVE WORK AREA REQUIREMENTS

General Requirements

Access only to trained personnel
Designed and constructed using ESD-protective materials and equipment
ESD characteristics certified, recorded, monitored, and corrected.

Minimum Requirements

No prime static generators
ESD-protective work surface (bench top and/or flooring)
Personnel wrist (and heel) ground straps (soft ground)
Ground strap checker/analyzer
Electrostatic field strength metre
ESD-protective packaging material
Paperwork segregated, unbound, or encased in ESD-protective material

Supplementary Requirements

Air ionizer(s)
Static sensor/monitor/alarm
ESD-protective clothing
Humidity controls
All energized tools and equipment grounded

NOTE: This summary is provided for reference only.
Paragraphs 307 and 308 requirements apply.

ANNEX C - PROTECTIVE WORKSTATION KITS

DESCRIPTION	
Wrist strap, electrostatic discharge, 1.5 m long coiled cord; used to tie on testers wrist and to test set, prevent static electricity from damaging instrument being tested. Contains built-in resistor and adjustable wrist strap with a 1 megohm resistor.	(NSN: 5920-01-274-0486)
Wrist strap, general, 3.0 m long coiled cord; used to tie on testers wrist and to test set to prevent static electricity from damaging instrument being tested.	(NSN: 5920-01-274-0487)
Workstation kit[5], electrostatic control, consisting of: 2 static dissipative rigid table mats, 1 common point ground system, 1 adjustable wrist strap cuff, 1 wrist strap cord with current limiting resistor, and 1 wrist strap connector, to be used in clean room environments or laminar flow booths where particulate control is necessary and ESDS devices are handled.	Type 1 (NSN: 4940-01-250-4235)
Workstation kit, electrostatic control, consisting of: 1 static dissipative soft table mat, 1 common point ground system, 1 adjustable size wrist strap cuff, 1 wrist strap cord with current limiting resistor, and 1 wrist strap connector to be used in all areas other than clean rooms or laminar flow booths where ESDS devices are handled and where physical shock protection against dropping is required.	Type II (NSN: 4940-01-250-4236)
Workstation kit, electrostatic control, consisting of: 1 static dissipative soft flexible portable work surface, 1 common point ground system, 1 adjustable size wrist strap cuff, 1 wrist strap cord with limiting resistor, and 1 alligator clip to be used in situations where other static control work-stations are not available, such as remote sites.	(NSN: 4940-01-250-4237
Workstation kit, electrostatic control, consisting of: 3 transparent waterproof electrostatic-protective, electrostatic-dissipative, heat sealable flexible pouches; 3 water-vapourproof electrostatic-protective, electrostatic and electromagnetic shielding heat-sealable flexible barrier bags; 2 adjustable snap wrist straps; 1 mat electrostatic dissipating; and 1 ground cord with a 1 megohm resistor.	Type III (NSN: 4940-01-253-5368)

[5] Commonly referred to as the field service kit.

ANNEX D - TEST PROCEDURES AND TEST EQUIPMENT

D10. GENERAL

1. In addition to the test methods and procedures listed herein, other nations' appropriate test procedures or relevant alternatives, e.g., those found in IEC 61340-5-1, may also be used to satisfy a specific or special test requirement.

2. Verification of specified test requirements may be done with the test equipment specified in paragraphs D30.1 through D30.10. The equipment may be obtained, as required, to verify that the electrical integrity of the electrostatic discharge (ESD) control products is maintained throughout the ESD-control products' usable lives. Relevant alternatives or additional equipment may be needed to satisfy a specific or special test requirement.

3. Periodic testing of items or materials used to control ESD is required in the time intervals specified. The test voltage for most ESD-controlled materials that require periodic testing is 10 volts to 100 volts depending on the expected resistance.

4. Additional tests may be carried out by mutual agreement between the supplier and the procurer. It should be emphasized that the tests in this section should be only carried out by personnel with the appropriate skills.

D20. TEST PROCEDURES

1. Work Surface.

a. The test equipment required to do work surface testing is specified in paragraph D30.5.

b. The work surface shall be tested annually in its existing environment.

c. All resistance measurements shall be taken at a minimum of 5 seconds after applying test voltage of 10 volts to 100 volts depending on the expected resistance.

d. Connect the positive lead from the megohmmeter to one of the 2.5 kg electrodes and the negative lead to the common ground point. Place the electrode near the rear edge of the work surface and approximately 900mm from the common ground point. Apply test voltage. Take reading and record. Repeat procedure placing the electrode in the center of the work surface and again near the forward edge of the work surface. Additional measurements taken should be between 2 and 4 measurement per square metre. Total resistance from top of work surface to ground point for each measurement shall be between $10^6\,\Omega$ and $10^9\,\Omega$.

e. If the measurements taken do not fall with the specified range, clean the work surface and probe with a 70 percent isopropyl-water solution using a clean, lint-free cloth. When dried, repeat step 1d. If the measurements

taken still do not fall within the specified range, the work surface shall be discarded and replaced.

f. For temporary work surfaces the ground connecting terminal shall be attached to the temporary work surfaces such that the grounding cord is connected to the top working surface. The connecting method for the earth ground point to the work surface shall be such that it does not permit any non-insulated earth grounding point component on the underside of the temporary work surface. The material for the temporary work surfaces shall be such that the surface resistivity and resistance to ground requirements given in table 3 are met.

2. Storage Cabinets and Shelves.

a. The test equipment required to test shelves, cabinets, and storage units is specified in paragraph D30.5.

b. All shelves, cabinets, and storage units shall be tested in their existing environment.

c. All resistance measurements shall be taken 5 seconds after applying test voltage of 10 volts to 100 volts depending on the expected resistance.

d. Connect the positive lead from the megohmmeter to one of the 2.5 kg electrodes and the negative lead to the ground point. For components mounted on a workstation, the negative lead will be the common point ground embedded in the work surface. The negative lead connection for shelves and cabinets not on static dissipative floors shall be to the verified ground point. For shelves and cabinets (not workstations) mounted on static dissipative floors, the negative terminal shall be a 2.5 kg electrode placed on the floor. Place the positive lead on a shelf/drawer and apply teat voltage. Three measurements shall be taken per drawer/shelf and recorded. This resistance from the surface of the component being tested to the ground point shall be between 10^6 and 10^9 Ω.

e. If the measurements taken do not fall within the specified range, clean the component being tested with a 70 percent isopropyl-water solution using a clean, lint-free cloth. When dried, repeat step 2d.

f. If the measurements taken still do not fall within the specified range the components shall be discarded or covered with a material that meets the prescribed resistance.

3. Static Dissipative Flooring

a. The test equipment required for testing installed flooring is specified in paragraph D30.5.

b. Flooring shall be tested annually in its existing environment and normal state of cleanliness.

c. All resistance measurements shall be taken 5 seconds after applying test voltage of 10 volts to 100 volts depending on the expected resistance.

d. The installed floor shall be subjected to surface to ground resistance measurements using the specified megohmmeter and electrode. The applied open circuit test voltage shall be 100 volts for each measurement.

e. Raised Floors.

(1) Resistance measurements are made by connecting the positive lead from the megohmmeter to the electrode and connecting the negative lead to the ground point. Remove a panel from the floor and connect the negative lead to an installed pedestal beneath the floor. Apply the test voltage. Take the measurement and record. Repeat for each measurement taken.

(2) A total of 5 equally spaced resistance measurements shall be taken for every $15m^2$ area of flooring. For floors with $< 15m^2$, one resistance measurement shall be taken for each 5 m^2 of flooring (equally spaced) with a minimum of 3 measurements per area.

The average of the total surface to ground resistance measurements shall be between 10^6 and $10^9\Omega$ with no individual measurement being above 5×10^9 or below $10^6\Omega$.

(3) If the floor fails to meet these specifications, the floor shall be thoroughly cleaned in accordance with the manufacturer's recommendations and retested as per paragraph 3f.

(4) If the floor still fails to meet these specifications, verify the calibration of the megohmmeter and retrieve the initially installed floor test results. Compare test results and determine if the readings are higher or lower than the initial readings. If higher, this may suggest that the floor has been waxed or coated. If so, the floor must be stripped and recleaned before retesting. If the readings are lower, a coating may have been added but with conductive properties. Again, stripping and recleaning will be necessary. These procedures should bring the floor within the specified resistance range.

f. Other Floors. The resistance measurement procedure is the same as for raised floors with the exception that the negative lead from the ohmmeter is connected to a point electrically the same as one of the acceptable points at which the floor is grounded. The number of test points, specified resistance range and retest processes are as specified in paragraph 3e(1) through 3e(4).

4. Wrist Strap.

a. The test equipment required for testing wrist straps is a wrist strap tester as specified in paragraph D30.2.

b. The wrist strap shall be tested before use in its existing environment while being worn.

c. Insert wrist strap connector into the socket on the wrist strap tester. With the hand opposite that on which the wrist strap is being worn, press the metal contact plate until either the green or red pass/fail light is illuminated. Ensure at the same time that the battery check light illuminates. If it does not, check the batteries. If it does, then observe the pass/fail light.

d. If the light illuminates, the wrist strap and cord are both good.

e. If the red light illuminates, disconnect the wrist strap cuff from the cord and connect the cuff end of the cord to the wrist fastener connection on the tester. Press the contact with a bare hand. If the green light illuminates, the cord is good. Discard the wrist strap cuff. If the red light illuminates, discard the cord.

f. Replace the wrist strap cuff or cord accordingly and repeat steps 4c through 4e.

5. Static Dissipative Footwear.

a. The test equipment required for testing static dissipative footwear is specified in paragraph D30.3.

b. A non-corrosive, 300mm x 300mm flat metal plate (min 1.5mm thick) is also required as a test footplate. Other materials (not aluminium) with a surface resistivity of $< 10^4\Omega$/sq. may be used to form the footplate.

c. The wearer should stand with both feet on the footplate.

d. The resistance from a contact with the hand to the foot-plate shall be $< 10^7\Omega$.

e. Toe and heel grounders shall be constructed such that the contact made with both feet meet the requirement for an electrical path from the wearer to contact points on each foot of the footwear in both toe and heel regions. A discrete resistor need not be incorporated in the toe or heel strap, as there is no minimum resistance requirement for this path.

f. Shoes shall be lab tested by random sampled lots annually. Nations' test method and resistance specification may be used.

g. Shoes will be replaced on an as needed basis determined by wear and condition of shoe in general.

6. Conductive/Static Dissipative Finger Cots and Gloves.

a. The equipment required for testing finger cots and gloves is specified in paragraph D30.3.

b. The finger cots and gloves shall be checked prior to being used.

c. The conductive material shall have a surface resistivity of 10^6 Ω/sq. or a surface dependent volume resistivity of 10^3Ω m (or 10^5Ω cm) per mm of material thickness.

d. If the measurements exceeds the maximum allowable resistivity, they will be replaced.

e. No reuse is allowed, and such items will be discarded after each use.

7. Static Dissipative Seating.

a. The equipment required for testing seating is as specified in paragraph D30.5. A non-corrosive, 915mm x 915mm flat metal plate (min 1.6mm thick) is also required as part of the test electrode.

b. Seating shall be tested annually in its existing environment. Do not clean the chair. Recover only those items that might interfere with the test.

c. All resistance measurements shall be taken 5 seconds after applying test voltage of 10 volts to 100 volts depending on the expected resistance.

d. The resistance of each tested seat shall be between 10^4Ω and 10^9Ω.

e. Place the seat on top of the metal plate ensuring that the plate is clean (no oxidation) and all casters of the seat are on the plate. Place one of the 2.5 kg electrodes from the test kit on the test plate between 2 seat casters.

f. Place the other 2.5 kg electrode from the test kit in the middle of the seat. Ensure that the contact surface of the electrode is clean (no oxidation).

g. Connect the positive lead from the megohmmeter to the electrode that is on the seat. Connect the negative lead from the megohmmeter to the electrode that is on the test plate.

h. Apply test voltage and record the resistance value.

i. If the measurement does not fall within the specified range, disconnect the negative lead from the electrode on the test plate and connect it directly to a metal point on the seat base. Reapply the test voltage and record the resistance value.

j. If the measurement in step 7i falls within the specified range, clean the casters of the seat thoroughly with 70 percent isopropyl-water solution using a clean, lint-free cloth. Allow to dry.

k. Repeat steps 7e through 7h. If the reading is still outside the specified range, replace the casters.

l. If the seat still does not meet the resistance requirement after changing the casters, replace the seat.

8. Relative Humidity.

a. The hygrometer required for monitoring the relative humidity (RH) is specified in paragraph D30.10.

b. The hygrometer shall be mounted at the workstation not move more than 1 metre above the level where ESDS devices are handled.

c. Where more than one workstation is contained in an area which has the same environment, a single hygrometer may be used to monitor the whole area.

d. When practicable, levels of 40 to 60 percent RH should be maintained.

(1) Excessive humidity can cause problems such as corrosion, possible leakage paths for high voltages and moisture contamination within equipment.

(2) Low humidity severely reduces the dissipation effectiveness of materials used in certain types of work surfaces, packaging, and clothing.

9. Bench Top Electrical Ionizers.

a. The test equipment required for testing bench top electrical ionizers is specified in paragraph D30.8 and D30.9. A standard measuring tape (min 2 m) is also required.

b. The ionizer shall be tested quarterly in its existing environment with the heater off and filters in place, if so equipped, and in a manner that will assure the air flow velocity discharges the charged plate. The air velocity shall be measured and recorded in the test results.

10. Discharge Time.

a. The equipment required to monitor the discharge time is specified in paragraph D30.8.

b. Place the charge plate monitor directly in front of the ionizer with the plate parallel to the front face of the ionizer at a distance of 0.30 m.

c. Turn the ionizer on, wait 30 seconds, charge the plate to +1000 volts and allow it to discharge to +50 volts. The charge plate monitor will measure the time it takes to discharge. Record the discharge time. Repeat procedure for -1000 volts. The discharge time for both the + and - initial plate voltages shall be $<$ 2 seconds.

d. Repeat steps 10b and 10c for plate to ionizer distances of 0.60 m, 0.90 m, and 1.20 m. The discharge times for these distances shall be $<$ 4 seconds, 7 seconds, and 10 seconds, respectively.

e. If the voltages do not discharge in the specified time, clean and balance the ionizer in accordance with the manufacturer's instructions.

f. Repeat steps 10b and 10c.

g. If the voltages still do not discharge in the specified time limit, the ionizer shall be discarded.

11. Offset Voltage.

a. The equipment required to monitor the offset voltage is specified in paragraph D30.8.

b. Place the charge plate monitor directly in front of the ionizer with the plate parallel to the front face of the ionizer at a distance of 152mm.

c. The plate shall be momentarily grounded to remove any residual charge and to verify zero for the monitor's circuitry.

d. Turn the ionizer on and allow it to operate for 1 minute or as necessary to allow reading to stabilize (max 5 min). Record the plate voltage. The voltage shall not exceed 25 volts.

e. If the measurement exceeds the maximum of 25 volts, follow the manufacturer's instructions for ion balancing. If the unit is self balancing or has no ion balancing ability, the unit shall be discarded.

f. After balancing, repeat steps 11b through 11d.

g. If the measurement still exceeds the maximum of 25 volts, the unit shall be removed from service and inspected.

12. Shielding Bags.

A visual inspection of shielding bags will be accomplished prior to each use. If the bag is torn, ripped, or the surface resistance of the bag is $> 10^4\Omega$, it will be discarded.

D30. TEST EQUIPMENT

1. Electrostatic Field Meter.

This device detects the presence of electrostatic fields emanating from a charged object. It is basically a tool for verifying whether or not electrostatic fields exist in the work place. It should not be used to make precise measurements. The ability of a material to generate charge can be roughly seen with the meter.

2. Wrist Strap Tester.

This device will allow the operator to check the integrity of his/her wrist strap cuff and cord. The tester allows for electrical continuity and resistance checks of both the wrist strap cord alone and of the entire wrist strap system while the operator is wearing it. It ensures that the wrist strap surface resistivity is $< 10^7\,\Omega$/sq., the resistance to ground is $< 10^7\,\Omega$, and the total resistance to ground is between $10^6\Omega$ and $10^8\,\Omega$.

3. Variable Voltage Megohmmeter.

This instrument will allow for measurement of static dissipative work surfaces, floors and shoes; single layer static dissipative garments; and the resistance of any other static control materials that require resistance in the 10^6 Ω to 10^9 Ω range.

4. Resistance Test Electrodes.

Two, 2.5 kg (+/- 0.5 kg), 64mm (+/- 1.5mm) diameter, flat-surfaced, non-corrosive metal (i.e., gold plated brass or stainless steel) electrodes of equal length are required to make the resistance measurements within the megohmmeters mentioned in paragraph D20.3. The electrodes are prepared by placing piece of heavy tin foil on a flat, hard, and smooth surface. On top of the foil, place a 64mm diameter disk of 6.4mm thick rubber that has a hardness of 50+/-10 as measured on a Shore Type A Durometer. Place the electrode on top of the rubber pad, draw the foil up around the rubber pad, and electrode, and secure the foil with a hose clamp. Repeat procedures for the second electrode. Electrodes that have conductive rubber do not need the tin foil, but the rubber pads need to be cleaned with 70 percent isopropyl alcohol solution. Conductive rubber electrode pads (64mm diameter x 6mm thick) can be used with the electrodes in lieu of the aluminum foil/rubber combination specified for the construction of the electrodes.

5. Megohmmeter Test Kit.

The kit contains the variable voltage megohmmetre and the 2.5 kg electrodes referenced above.

6. Ohmmeter.

The ohmmeter is used to check the integrity of grounding conductors and bonding devices for ESD-controlled workstations, cabinets, and floors.

7. Ground Impedance and Utility Wiring Verification Meter.

This meter is required for measuring the wiring accuracy in electrical systems and assuring that ground conductors (third wire) in power systems are effective for static dissipative and safe for personnel usage. The meter is capable of analyzing the hot, neutral, and equipment ground conductors of an electrical system. It will measure the impedance of equipment ground conductors to verify the integrity of the ground point used in grounding static control workstations, cabinets or floors.

8. Charged Plate Monitor.

A charged plate monitor is used to verify the performance of bench top ionizers by measuring charge decay times and offset voltages. It shall have a 152mm x 152mm conductive plate (20 pf capacitance maximum) for a sensor. The monitor shall be capable of measuring decay times from initial plate voltages of + or - 1000 volts to + or - 100 volts, respectively.

9. Hygrometer.

A hygrometer is required to measure the percent of relative humidity (RH) within a specified work area. The instrument is a precision direct reading hygrometer calibrated in RH with an accuracy of $<$ 10% over the range 25% to 80% RH.

10. Equilateral Triangle Plate Electrode.

Surface resistance may be tested by using a tested tripod electrode base on a conductive plate in the shape of an equilateral triangle (each side 180mm) according to IEC 364-6-61. Soaking of the surface of the measured material with a liquid with a measured resistance of 10-100Ω is required. An electrode load of 750N is required for floor measurement and 250N for wall, working tables, and transport boxes.