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Space Administration

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

QD01

MSFC TECHNICAL STANDARD

**REQUIREMENTS FOR
ELECTROSTATIC
DISCHARGE CONTROL**

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DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Baseline		02/05/99	Initial Release.
Revision	A	09/01/00	Converted document to new template. Revised document to delete references to previous "MSFC-P" documents. Changed "Quality Assurance" to "Safety and Mission Assurance (S&MA)".
Revision	B	06/21/06	Updated document per NASA Headquarters Rules Review. Updated "SCOPE" to identify the applicable Electrostatic Discharge (ESD) standard for propellant and explosive devices, and replaced MIL-STD-1686 with ANSI/ESD S20.20-1999 in the second paragraph. Updated the "APPLICABLE DOCUMENTS" section to remove canceled, or add replacement documents. Replaced MIL-STD-1686 with ANSI/ESD S20.20-1999, and added MIL-STD-1800. Updated the "DEFINITIONS" section. Updated the "GENERAL REQUIREMENTS" section, item "a" with the following: "The minimum protection for ESDS design shall be as specified per the engineering documentation, or 2000 volts for assemblies and 4000 volts for components and equipment." Updated paragraph 5.1.1 titled "Packaging" changing 10 ⁹ to 10 ¹² in the second sentence. Updated paragraph 5.1.3 titled "Kitting and Shipping" adding the following to the last sentence: ", or as specified per the requirements of paragraph 5.1.1 herein." Updated the requirements for "Equipment and Facility Grounding" per paragraph 5.4. Replaced MSFC-RQMT-1493 with MSFC-RQMT-2918 in paragraph 6.4. Deleted the last sentence of paragraph 7.1. In the first sentence of paragraph 7.2, change "ground" to "grounding". Updated paragraph 10.5. Updated Figure 1. Added Figure 2.
Revision	C	10/18/12	Revision C release; document is authorized through MPDMS. Major rewrite. This document was updated using NASA-HDBK-8739.21 to provide standardized guidance based on Agency-level best practices.

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FOREWORD

This document provides requirements for prevention of electrostatic discharge (ESD) events and for protection of hardware from ESD. The document shall be applicable to MSFC in-house activities for flight hardware. This document has been tailored to comply with the requirements of ANSI/ESD S20.20 as specified per NASA Policy Directive (NPD) 8730.5, NASA Quality Assurance Program Policy. The NASA-HBDK-8739.21 was also used to provide standardized guidance based on Agency-level best practices.

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1.0 SCOPE

This document provides a consistent application of requirements for an electrostatic discharge (ESD) control program for electrical or electronic assemblies, equipment, and their constituent parts susceptible to damage from ESD. This document shall not apply to ESD requirements for electrically initiated explosive devices. For propellant and explosive devices, reference MSFC-STD-1800 or other approved procedures.

This document shall be for use internally at MSFC and shall not be invoked or specified on contracts. Use ANSI/ESD S20.20 or other approved ESD control procedures for contracts. This document shall apply to all MSFC organizational elements involved in the design, procurement, receiving, inspection, fabrication, test, handling, storage, and operation of flight and flight associated hardware containing ESD sensitive items for MSFC projects. Specifically, these requirements shall apply to the following personnel as a minimum: electrical designers, engineers who troubleshoot electrical hardware, manufacturing personnel, quality assurance (QA) personnel, shipping/receiving personnel, kitting personnel, and electrical test personnel.

2.0 APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

<u>Document Number</u>	<u>Title</u>
ANSI/ESD S1.1	Wrist Straps
ANSI/ESD STM3.1	Ionization
ANSI/ESD S4.1	Worksurfaces-Resistance Measurements
ANSI/ESD S6.1	Grounding
ANSI/ESD S7.1	Floor Materials Characterization of Materials
ANSI/ESD STM12.1	Seating-Resistive Measurement
ANSI/ESD STM13.1	Electrical Soldering/Desoldering Hand Tools
ANSI/ESD S20.20	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)
ANSI/ESD TR20.20	Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment
ANSI/ESD TR53	Compliance Verification of ESD Protective Equipment and Materials
ANSI/ESD STM97.1	Floor Materials and Footwear-Resistance Measurement in Combination with a Person

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MIL-STD-129	Standard Practice Military Marking For Shipment And Storage
MWI 3410.1	Marshall Work Instructions (MWI), Personnel Certification Program
NASA-HDBK-8739.21	Workmanship Manual for Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)
NPD 8730.5	NASA Quality Assurance Program Policy
NFPA 70	National Electrical Code

2.2 REFERENCE DOCUMENTS

MSFC-STD-1800	Electrostatic Discharge (ESD) Control For Propellant and Explosive Devices
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3.0 DEFINITIONS

- a. Antistatic. Usually refers to the property of a material that inhibits triboelectric (friction) charging. NOTE: A material's antistatic characteristic is not necessarily correlatable with its resistivity or resistance.
- b. Conductive Material. A material that has a surface resistance of less than 1×10^4 ohms.
- c. 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 two bodies at different electrostatic potentials as they approach one another. Details of such processes, such as the rate of the charge transfer, are described in specific electrostatic discharge models.
- d. Electrostatic Discharge Sensitive (ESDS). The ESD level that causes component failure.
- e. Electrostatic Field. An attractive or repulsive force in space due to the presence of electric charge.
- f. Equipment Grounding Conductor. The conductor used to connect the non-current carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both at the service equipment.
- g. ESD Protected Area/Workstation. Area or workstation constructed and equipped with necessary ESD protective materials, equipment and procedures to limit ESD voltages below the sensitivity level of handled ESDS items. A protected area differs from a workstation by

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accessibility. Access to protected areas is limited to certified personnel or personnel escorted by certified personnel.

h. Ground. 1) A conducting connection, whether intentional or accidental between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth. 2) The position or portion of an electrical circuit at zero potential with respect to earth. 3) A conducting body, such as the earth or the hull of a steel ship or vehicle, used as a return path for electric currents and as an arbitrary zero reference point.

i. Groundable Point (G_p). Any point with low impedance to ground where grounding may be attached. Usually, it is the common point ground (CPG).

j. Grounded. Connected to the earth or some conducting body that serves in place of the earth.

k. Grounded Conductor (i.e., the Neutral conductor). A system or circuit conductor that is intentionally grounded.

l. Grounding Electrode(s). A metal underground water pipe, metal frame of a building or structure, ground ring encircling a building or structure, or an iron or steel rod/pipe/plate electrode in direct contact with the earth and electrically continuous to the points of connection of the grounding electrode conductor and bonding conductor/jumper.

m. Grounding Electrode Conductor. The conductor used to connect the grounding electrode(s) to the equipment grounding conductor, to the grounded conductor, or to both, at the service equipment.

n. Hard Ground. A connection to earth ground either directly or through low impedance.

o. Human Body Model (HBM). The most commonly used model for ESD sensitivity levels of electronic devices. This model reflects the discharge effects when a person touches an electronic device. The HBM classifications are specified in accordance with the requirements of ANSI/ESD S20.20 and other approved ESD documents.

p. Impedance. The total opposition (i.e., due to resistance and reactance) a circuit offers to the flow of alternating current. It is measured in ohms and the lower the ohmic value, the better the quality of the conductor.

q. Raceway. An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars.

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

s. Static Dissipative Materials. ESD protective material having surface resistivities greater than 1×10^5 but not greater than 1×10^{12} ohms per square.

t. Surface Resistance. The ratio of DC voltage to the current flowing between two electrodes of specified configuration that contact the same side of a material. This measurement is expressed in ohms.

u. Surface (Sheet) Resistivity. The surface resistivity is an inverse measure of the conductivity of a material and equal to the ratio of the potential gradient to the current per unit width of the surface, where the potential gradient is measured in the direction of the current flow in the material. (Note: Surface resistivity is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial. Surface resistivity applies to both surface and volume conductive materials and has the value of ohms per square.)

v. Triboelectric (friction) charging. The generation of electrostatic charges when two materials make contact or are rubbed together, then separated.

4.0 GENERAL REQUIREMENTS

ESD controls, as a minimum, shall be implemented to include the following ESD control program requirements:

- a. The minimum protection for ESDS design shall be as specified per the engineering documentation.
- b. Protected areas and work stations shall be established and verified as adequate by Safety and Mission Assurance (S&MA) personnel prior to their use.
- c. Use of protective personnel clothing and proper personnel grounding at all necessary points where unprotected or unpacked ESDS items are handled.
- d. Establish a certification program to ensure that all personnel handling ESDS items have received the necessary training and have been certified.

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e. Initial certification training shall be obtained before personnel handle ESDS items. ESD recertification training shall be required every two (2) years.

f. Perform internal audits to ensure the integrity of the ESD protected areas and equipment.

g. Inspection of documentation for ESD markings, precautions, handling procedures, and compliance verification records (i.e., test measurement results), as applicable.

h. ESD testing and monitoring equipment used in protected areas or at workstations shall be calibrated in accordance with the manufacturer's instructions.

i. ESDS devices and assemblies containing ESDS parts susceptible to ESD voltage levels less than 100 volts HBM shall be identified as such on engineering documentation. A specific procedure, prepared in cooperation with the cognizant program/systems engineer, shall be documented for the susceptibility voltage level when such parts are present.

5.0 DETAILED REQUIREMENTS

5.1 Handling. Handling and moving of ESDS items shall be accomplished using appropriate ground straps, grounding chains, and/or protective packaging. Detailed ESD procedures shall be developed to minimize occurrence of discharge when handling of ESDS items where ESD protection is not practicable.

5.1.1 Packaging. Electrostatic protective packaging shall both prevent the generation of a charge and protect the items from strong electrostatic fields. Materials used in protective bags and pouches shall be constructed from a single folded piece of material and the surface resistance of any material shall be greater than 1×10^5 ohms and not exceed 1×10^{12} ohms. If bags or pouches are not transparent to allow identification of contents without removal, a label shall be placed on the outside of the bag or pouch that identifies its contents. Non-metallic conductive or static dissipative magazines, chutes and dip-tubes shall be used for shipping integrated circuits. Tote boxes and covers shall be made of conductive or static dissipative material. For devices that are sensitive to damage from 100 volts or less (e.g., unprotected gate oxide devices), double bagging (a static dissipative bag inside a metal foil bag) shall be required.

5.1.2 Receiving. All ESDS items received shall be examined for proper ESD precautionary marking and for ESD protective packaging. Inadequate precautionary markings shall be corrected prior to further processing. When an item is received that has not been protected during shipment or internal transfer, it shall be rejected as defective and processed as nonconforming material.

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5.1.3 Kitting and Shipping. When a kit is assembled that includes an ESDS item, the entire kit shall be packaged and marked as ESDS. The accompanying documentation (i.e., paperwork) shall identify the kit as ESDS. Paperwork (e.g., QA records, routing slips, travelers, instructions, etc.) accompanying an ESDS item shall be contained in static dissipative bags or envelopes, or packaged separately from the packaging used to protect ESDS items. Paperwork shall not come in physical contact with an ESDS item. ESDS items packaged for shipping shall be packaged and marked as required by the contract, or as specified per the requirements of paragraph 5.1.1 herein.

5.1.4 Component Testing (Black Box). Wrist straps shall be worn when connecting cables to boxes unless the box design precludes ESD damage due to discharge into connector pins. Environmental controls during testing shall be in accordance with the associated test procedure.

5.2 Protective Areas/Workstations. The protective areas and workstations shall be maintained in a clean and orderly condition. Smoking, eating and drinking shall not be permitted.

5.2.1 Access. Protective areas shall be clearly identified by prominently placed signs. Access to such areas shall be limited to certified personnel. All other personnel shall be escorted and equipped with protective clothing, as required. It is recommended that all personnel coming within 1 meter (3.3 feet) of any ESDS item are required to wear an ESD protective garment (smock) and a personnel grounding device. See paragraph 5.3 herein.

5.2.2 Work Surfaces. All work surfaces in ESD protected areas and at protective workstations shall be static dissipative and electrically connected to a common point ground. Refer to Figures 2 and 3 to see a typical ESD grounded workstation layout and workstation common point ground connections, respectively. ESD work surface materials (e.g., table mats, floor coverings, floor mats, paints, coating, field service mats, etc.) shall have surface resistance in the range of 1×10^5 to 1×10^9 ohms. Work surfaces shall be kept free of static generating materials (e.g., common plastics, Styrofoam, bubble pack, tape, personal items such as radios, pictures, hair combs or brushes, coffee mugs, cell phones, iPADS, etc.).

When process-essential insulators (e.g., some tools and jigs) are required at the workstation or during any operation where unprotected ESD item are handled the following shall apply:

If the electrostatic field exceeds 2000 volt/inch, steps shall be taken to either:

- a. Separate the insulators from the ESD-sensitive device by a minimum distance of 12 inches (for Class 0 devices increase the minimum distance to 18 inches), or
- b. Use ionization or other charge mitigating techniques to neutralize the charge.

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The electrostatic field can be measured using an electrostatic field meter in accordance with the manufacturer's instructions.

Cathode ray tubes used in monitors and various test equipment generate significant static charges on their glass surfaces and electromagnetic fields in their vicinity. Both of these issues shall be addressed in local procedures when they are necessary at the workstation.

5.2.3 Flooring. ESD protective floors or grounded ESD protective floor mats shall be mandatory in areas where personnel are not wearing wrist straps. Under these conditions the use of conductive or static dissipative leg straps, heel straps, or shoes shall be mandatory. ESD protective floors or mats shall be kept free of dust, dirt, and other contaminants. After each cleaning, the floor resistivity of ESD protective floors or mats shall be verified and the results shall be recorded. ESD protective floors shall not be waxed or buffed unless the flooring manufacturer's recommendations are followed and the materials used do not inhibit the conductive or static dissipative properties of the flooring.

5.2.4 Air Ionizers. When the use of air ionizers is necessary, they shall either incorporate a continuous balance status indicator (alarm) or be placed on Category I calibration (recall) with the interval established by the calibration laboratory.

5.3 Personnel Grounding Devices. Grounding devices shall be supplied to all personnel working with or handling ESDS items to prevent electrostatic charge buildup. A grounding device shall be worn continuously by all personnel while working with unprotected ESDS items.

5.3.1 Wrist Straps. Wrist straps shall ensure conductive contact with the wearer's skin. The safety resistor shall measure 1 mega-ohm (+/- 20%). Wrist strap monitors that alarm when the connection to ground is compromised are preferred. When individuals are seated at ESD-protective workstations, they shall be connected to the ESD ground using a wrist strap.

5.3.2 Foot Grounding Devices. Conductive or static dissipative foot grounding devices, such as leg, toe, heel straps, or shoes worn in conjunction with ESD protective flooring and/or ESD protective mats, shall be acceptable alternatives to wrist straps in those situations where the operator needs to be mobile and the use of a wrist strap is impractical or unsafe.

5.4 ESD Grounding System Verification. The preferred practice is to use the third wire (i.e., equipment grounding conductor) of an AC (alternating current) wall outlet to ground all items at the ESD-protected workstation. Grounding procedures must remain consistent with the National Electrical Code (NFPA 70). Prior to performing ESD grounding system verification, check for proper wiring within the AC wall outlet containing the equipment grounding conductor to be used for the ESD ground. Verify the following wiring conditions:

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- a. Neutral and equipment grounding conductor wires are present and not connected to each other at the wall outlet.
- b. Hot and neutral conductors are not reversed at the wall outlet.
- c. Hot and equipment grounding conductors are not reversed at the wall outlet.

The equipment grounding conductor will, hereafter, be referred to as the AC equipment ground. Refer to Figure 4 for identification of AC wall outlet conductors and preferred connections.

5.4.1 AC Equipment Ground. Using an ohmmeter measure the resistance between the common point ground and the previously tested AC equipment ground. The measurement probes shall be placed to include the resistance of all interconnecting and securing devices at the ESD-protected workstation. Refer to Figure 5 which shows the measurement test points. The total resistance shall not be greater than 1 ohm.

5.4.2 ESD Technical Elements. Using an ohmmeter, measure the resistance between the common point ground and the groundable point of an ESD technical element (e.g., work surface, flooring, wrist strap, etc.). The measurement probes shall be placed to include the resistance of all the interconnecting and securing devices. The resistance shall not exceed 1 ohm or be within $\pm 20\%$ of the designed resistance value for the workstation, including the optional resistor value as recommended by the manufacturer of an ESD technical element. Refer to Figures 2 and 3 to show examples of interconnecting and securing devices to be included in the measurement.

5.4.3 Facilities with AC Equipment Ground and Auxiliary Ground. When both the AC equipment ground and an auxiliary ground (i.e., metal underground water pipe, metal frame of building, ground ring, etc.) are present and electrically bonded together within the facility, the following measurement shall be conducted. First, verify the AC equipment ground as specified per paragraph 5.4. Next, using an ohmmeter, measure the resistance between the AC equipment ground and any auxiliary ground. The measurement probes shall be placed to include the resistance of all interconnecting and securing devices. Refer to Figures 2 and 3 to show examples of interconnecting and securing devices to be included in the measurement. The total resistance shall not be greater than 25 ohms.

5.4.4 Field Service/Equipotential Bonding (Applications without AC Equipment Ground). This electrically interconnecting method applies to remote or field service applications where an AC equipment ground is not present. Refer to ANSI/ESD S6.1 for the ESD requirements applicable to this method.

5.5 Accessories. ESD protective furniture (e.g., chairs or stools) can be used at workstations or in protected areas, but it is not required. The wrist strap system serves as the primary means of protection. If used, the ESD protective furniture shall be constructed of conductive material and

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the cover material fabricated from static dissipative materials. Where carts, wagons, or trams are required to be grounded and approved ESD protective floors are utilized, positive electrical contact shall be made between the floor and conductive structure of the vehicle. If non-ESD protective floors are present, the vehicle shall be grounded before ESDS items are loaded or removed from the vehicle. The vehicle having a permanently attached ground snap or common point ground connector for grounding the vehicle when docked in an ESD protected area or at an ESD workstation is highly recommended.

5.6 Humidity. The relative humidity shall be maintained in ESD-protected work areas at 30 percent to 70 percent. For highly sensitive ESD (e.g., HBM Class 0) items, the humidity level shall be in the range of 40 percent to 70 percent. At levels below 30 percent (< 40 percent for Class 0 items), additional precautions shall be employed (e.g., air ionizers, humidifiers). If other cautionary methods are not available or if all attempted mitigation techniques are not successful, work shall be halted until the required humidity level is obtained.

5.7 Identification and Marking. ESDS items, equipment, and assemblies shall be identified in compliance with the following requirements. Identification shall be placed so as to warn personnel before any ESD damaging procedure can be performed. Packing lists, inspection reports, travelers, and other paperwork accompanying the hardware shall contain ESDS labels and precautionary notes.

a. Equipment containing ESDS items shall be identified internally with either the sensitive electronic device symbol from MIL-STD-129 or the Electronic Industries Association RS-471 symbol. The following caution statement shall be placed adjacent to the ESDS symbol if room is available: CAUTION - CONTAINS PARTS AND ASSEMBLIES SUSCEPTIBLE TO DAMAGE BY ESD.

b. Equipment having external sensitivity shall have ESDS symbols affixed to their exterior.

c. The ESDS cautionary mark on an assembly shall be visible when the assembly is installed in the next higher assembly. Alternative identification shall be used as approved by the NASA procuring organization when the prescribed marking is not possible.

5.8 Monitoring.

5.8.1 Periodic Compliance Verification Testing. The responsible organizations (users/operators) shall comply with periodic compliance verification testing, as specified per Table 1 herein or other approved methods, of equipment and materials used in their ESD protective areas/workstations. Note that each periodic test listed in Table 1 may not apply to every ESD protective area/workstation.

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5.8.2 Daily Test Measurements. The resistance of all personnel grounding devices that do not use an audible alarm shall be verified and recorded daily by the responsible organization.

a. Daily testing of ESD wrist straps may be omitted if a Continuous Monitoring System (CMS) is used. The use of a CMS is the preferred method, and is also highly recommended for Class 0 ESD protected areas/workstations. CMS equipment with both audible and visual alarms is recommended. Both alarms should activate when the when the wrist strap is temporarily removed, or when the grounding integrity is compromised (e.g., loose ground connection, defective wrist strap or cord, loose contact between the wrist strap and the wearer's skin, etc.).

b. Note that if foot grounding devices are used in an ESD protected area, daily testing shall be required and the test results recorded by the responsible organization. Foot grounding devices must be worn on both feet and tested one foot at a time. Foot grounding devices shall be tested each time an individual enters an ESD protected area.

5.8.3 Audits. Initial verification audits shall be performed by the S&MA personnel upon request using MSFC Form 4294 as a guide. Verification of current status shall be accomplished by the following:

a. During MSFC internal audits, organizations with protected areas/workstations shall be periodically audited for compliance with this document.

b. Spot audits shall be performed by S&MA personnel on a random basis using MSFC Form 4294 as a guide to further assure compliance with this document.

6.0 NOTES

6.1 For the purpose of this document, parts assemblies and equipment susceptible to ESD voltages of 16,000 volts or higher are considered non-ESD sensitive.

6.2 Surface resistivity changes exponentially with humidity changes. Therefore, relative humidity levels maintained between 40 percent and 60 percent are recommended.

6.3 The S&MA Office will assist in performing periodic testing when requested.

6.4 This document replaces MSFC-RQMT-2918 dated June 21, 2006.

7.0 SAFETY PRECAUTIONS AND WARNINGS NOTES

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7.1 Work surfaces should be soft grounded to eliminate the safety hazard of touching a high voltage (i.e., between 110 to 250 volts) circuit with one hand and a hard ground with the other.

7.2 Before altering or connecting any line from an additional ground rod to the equipment grounding conductor (EGC), consult with a qualified electrician or safety representative. The bond connection and lines must be able to carry fault and lightning strike currents.

8.0 APPENDICES, DATA, REPORTS, AND FORMS

MSFC Form 4294 ESD PROTECTED AREA/WORKSTATION AUDIT

9.0 RECORDS

The completed MSFC Form 4294 shall be maintained by the S&MA Office for 10 years from the audit date or as long as the protected area/workstation is in existence. The records for periodic compliance verification testing and daily test measurements required by paragraphs 5.7.1 and 5.7.2 will be maintained by the organization responsible for the protected area/workstation for 3 years.

10.0 TOOLS, EQUIPMENT, AND MATERIALS

10.1 Insulated metal hand tools such as pliers, cutters, tweezers, and wire strippers are prohibited. Static dissipative solder extractors are preferred over anti-static solder extractors made of metal, or having a metallized plastic barrel and tip. Plastic solder extractors are not allowed unless fabricated from a static dissipative material. Electrical tools shall have a three-wire grounded power cord or be double insulated, and the area making contact with the work piece shall be grounded with a measured resistance not to exceed 20.0 ohms. All electrical tools used in proximity of unprotected ESDS items shall be connected electrically through a ground fault interrupter circuit.

10.2 Cold chambers shall have the conductive baffles and shelves within the chamber grounded. The ESDS items shall be contained within or mounted on conductive material. The stability of ESD protective materials, which are used in temperature chambers, should be suited for the test temperature and humidity ranges.

10.3 Cleaning agents and methods used on ESDS protective items shall not reduce the effectiveness of these items. They shall not cause leaching or leave insulating residues. Cleaning agents shall be chosen for low electrostatic charging propensity. ESDS items shall only be cleaned with solvent wetted brushes and/or wipes.

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10.4 A wrist strap tester shall be available in all areas where ESDS items are handled. Footwear testers also shall be available in all ESD protected areas where foot grounding devices are used.

10.5 ESD protective smocks shall be constructed such that their static dissipative or conductive properties are continuous and consistent throughout the material. The ESD protective smocks shall be buttoned (except for the collar) whenever the wearer is at an ESD protective workstation or in a designated ESD protective area. As an additional precautionary measure, ground the smock either by connecting it to a grounded wrist strap, or by using a ground cord from the hip connection of the smock to a groundable point when working at a stationary location. Either the disposable-type or washable ESD smocks are acceptable, as preferred by the user/operator. The manufacturer's instructions for installation, testing, and maintenance/cleaning shall be followed to gain maximum effectiveness and use from the smocks. Finger cots and gloves, when worn in an ESD protective area, shall be made of static dissipative or conductive materials.

10.6 When spraying ESDS printed wiring assemblies with conformal coating, an anti-static spray nozzle shall be used.

11.0 PERSONNEL TRAINING AND CERTIFICATION

Certification of personnel shall be based on successful completion of an approved training program. This training is for those individuals who play a major role in ESD damage prevention. These individuals include, but are not limited to, electrical designers, engineers who troubleshoot electrical hardware, manufacturing personnel, QA personnel, shipping/receiving personnel, kitting personnel, and electrical test personnel. The training shall include the following: ESD control program, principles/control methods of static electricity, identification of ESDS items, protective materials and equipment, protected areas and work stations, monitoring of the work place, handling ESDS items, packaging, marking and shipping of ESDS items. After successful completion of training, personnel shall receive a badge shown in Figure 1 as evidence of certification. In order to maintain ESD certifications, recurrent training and recertification shall be required every two (2) years. Reference Chapter 5 of MWI 3410.1, Personnel Certification Program, for the requirements associated with training and certifications.

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Figure 1: ESD Certification Badge

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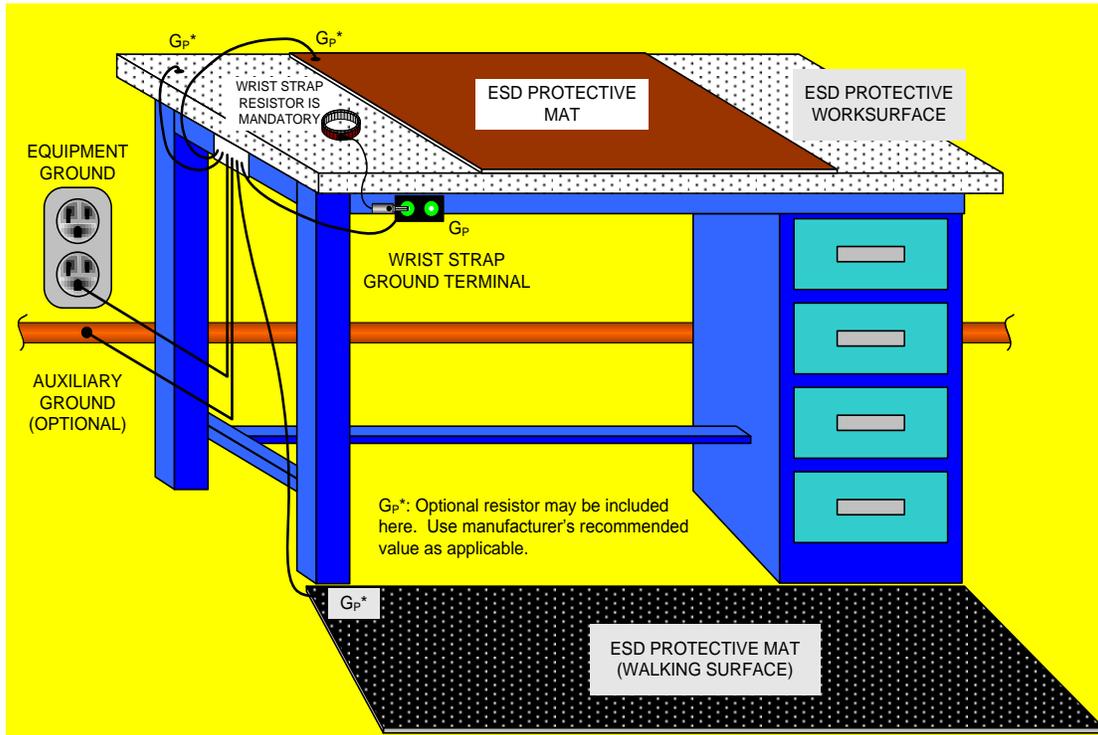


Figure 2: Typical ESD Grounded Workstation Layout

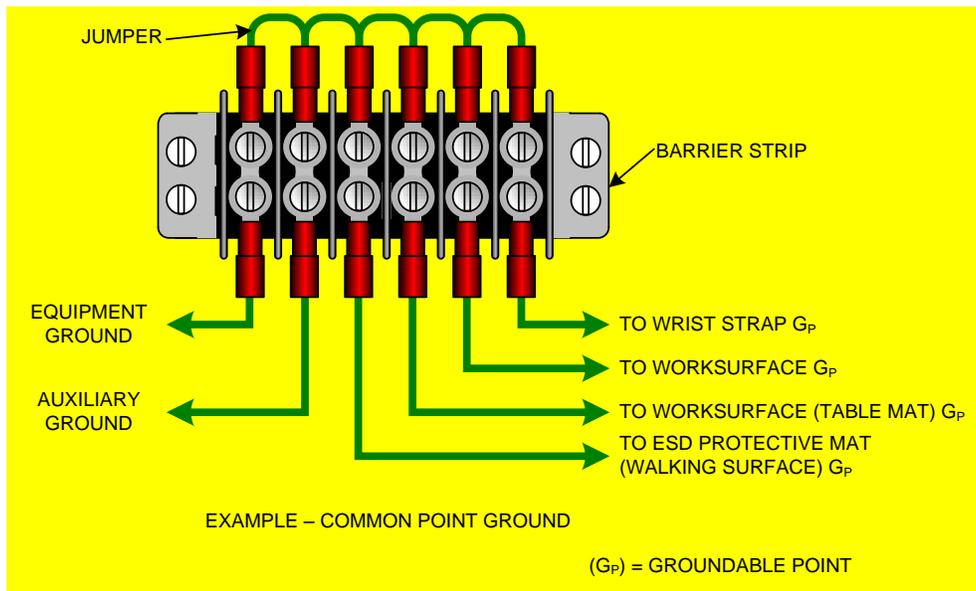


Figure 3: Workstation Common Point Ground Connections

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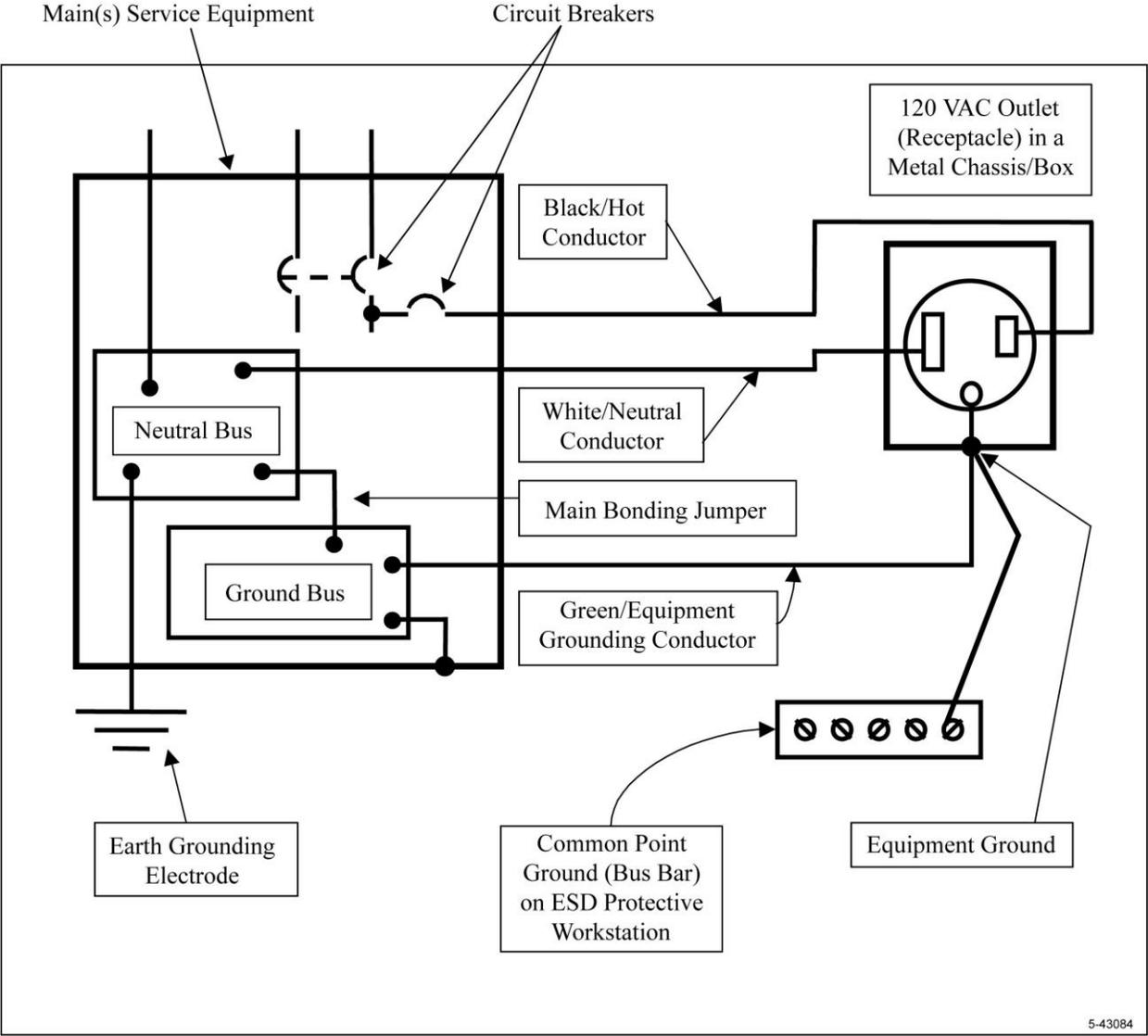


Figure 4: Preferred Ground Connection and Main(s) Service Equipment

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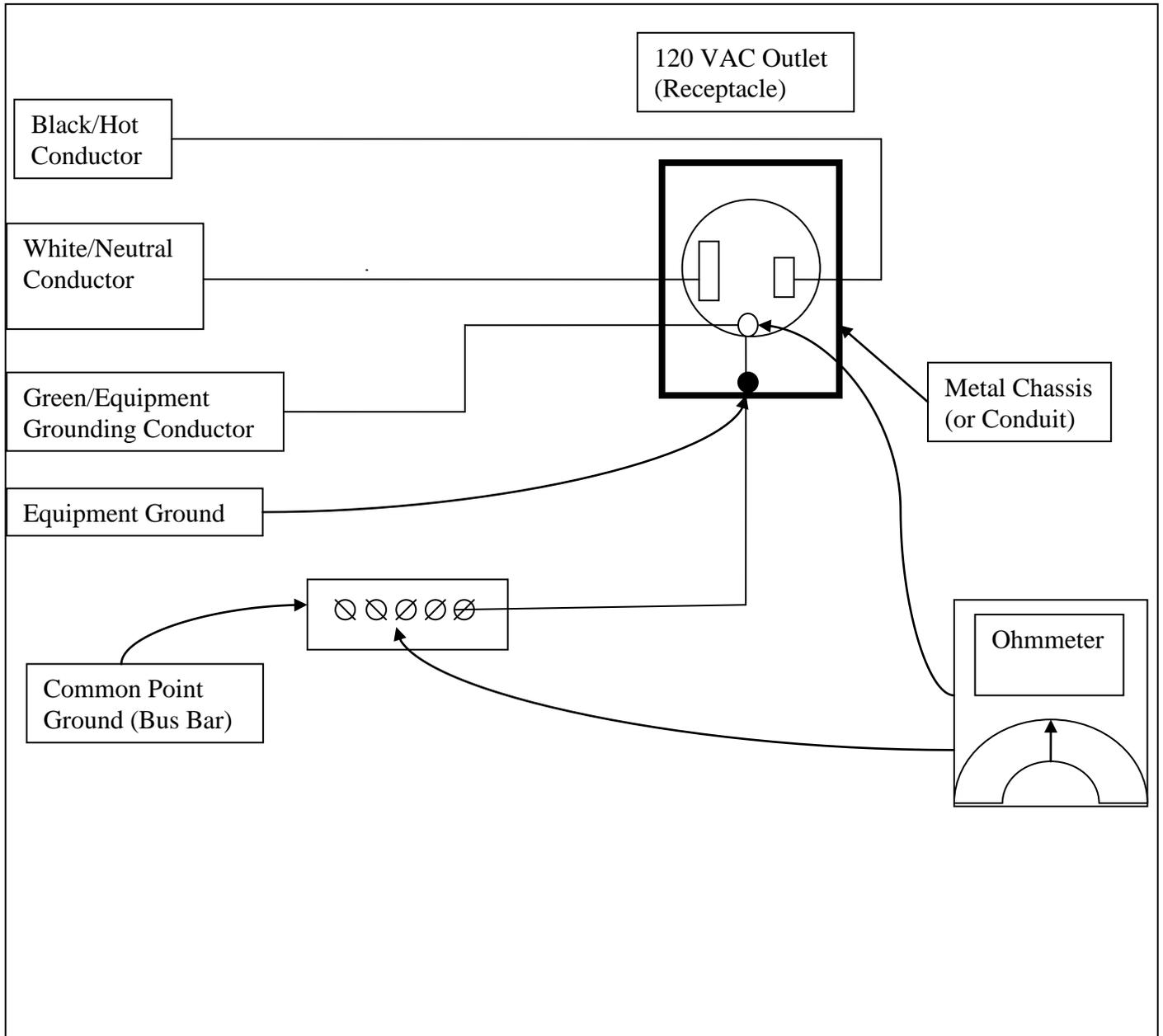


Figure 5: AC Equipment Ground Resistance Measurement Test Points

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Table I. ESD Compliance Verification Schedule and Measurements

Test #	ITEM	Test Method Ref.	Test Parameters	Verification Intervals				
				Continuous	Daily	Weekly	Quarterly ⁴	Annual
1	² Work Surface Resistance from point to point	ESD TR53; and ANSI ESD S4.1	$\geq 1 \times 10^6$ ohms and $< 1 \times 10^9$ ohms measured between two points 10 inches apart in the most commonly used portion of the work surface .				X	
2	Work Surface Resistance to groundable point	ESD TR53; and ANSI ESD S4.1	$> 1 \times 10^5$ and $< 1 \times 10^9$ ohms from the center of the work surface to the equipment ground.				X	
3	^{1,2} Protective Floor Resistance	ESD TR53; and ANSI ESD S7.1	$< 1 \times 10^9$ ohms. After cleaning the floor shall be checked and the data recorded.				X	
4	^{1,2} Protective Floor Grounding	ESD TR53; and ANSI ESD S7.1	$> 1 \times 10^5$ and $< 1 \times 10^9$ ohms from the floor surface to the equipment ground.				X	
5	³ Wrist Strap Check Resistance	ESD TR53; and ANSI ESD S1.1	1×10^6 ohms \pm 20% or user defined value. Use approved Wrist Strap checker and log daily. Daily testing may be omitted if a Continuous Monitoring System (CMS) is used, which is the preferred method.		X			
6	Ground Point Resistance of an ESD Technical Element	ESD TR53; and ANSI ESD S6.1	< 1 ohm impedance from Groundable Point (Gp) to the Equipment Ground, or \pm 20% of the designed resistance value for the workstation including the optional resistor value recommended by the manufacturer of the ESD Technical Element.				X	
7	³ Foot Grounding Device Integrity	ESD TR53; and ANSI ESD STM97.1	$< 35 \times 10^6$ ohms and use approved footwear checker & log each time you enter the area.		X			
8	² ESD Continuous Monitoring System	ESD TR53	Verify functionality before handling ESDS items. Check alarm limits annually per Manufacturer's instructions.	X				X

¹ Additionally, the Protective Flooring resistances are checked and documented after the floor or floor mats have been cleaned. The area does not need to be checked after vacuuming.

² These items require proof of verification. (i.e. sticker or log entry)

³ Automatic data loggers may be used for wrist strap and foot grounding daily checks.

⁴ For ESD protected areas/workstations designated for handling HBM Class 0 devices, the intervals may be performed monthly as a minimum.

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Table I. ESD Compliance Verification Schedule and Measurements (continued)

Test #	ITEM	Test Method Ref.	Test Parameters	Verification Intervals				
				Continuous	Daily	Weekly	⁴ Quarterly	Annual
9	² Stool / Chair Grounding.	ESD TR53; and ANSI ESD STM 12.1	< 1 x 10 ⁹ ohms to the chair's groundable point. For Class 0 Work Areas only, verify monthly.					X
10	² Carts	ESD TR53; and ANSI ESD S4.1	< 1 ohm if tied directly to the common point ground (CPG) or equipment ground. < 1 x 10 ⁹ ohms when grounded thru conductive flooring, referenced to CPG.					X
11	Relative Humidity (RH)	N/A	30 to 70% RH continuous for work area. For Class 0 Work Areas RH shall be > 40%. Calibrate annually per the Manufacturer's recommendations.	X				X
12	² Ionizers	ESD TR53; and ANSI ESD STM3.1	Discharge time: User defined Offset voltage: < ± 50 Volts				X	
13	⁵ Soldering Iron Tip to Ground Resistance	ESD STM13.1; and ESD TR20.20	Verify first that the voltage is < 2.0 mVAC to the common ground point; then verify that resistance is < 20 ohms to the common point ground during periodic verification.			X		
14	AC Equipment Ground	ESD TR53; and ANSI ESD S6.1	< 1 ohm total resistance.				X	
15	Auxiliary Ground	ESD TR53; and ANSI ESD S6.1	< 25 ohms total resistance.				X	

¹ Additionally, the Protective Flooring resistances are checked and documented after the floor or floor mats have been cleaned. The area does not need to be checked after vacuuming.

² These items require proof of verification. (i.e. sticker or log entry)

³ Automatic data loggers may be used for wrist strap and foot grounding daily checks.

⁴ For ESD protected areas/workstations designated for handling HBM Class 0 devices, the intervals may be performed monthly as a minimum.

⁵ Soldering systems that incorporate sensing circuits to verify connections to ground and power down the system when out of range are exempt from this verification schedule.

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Table II. Recommendations Applicable to HBM Class 0 ESD Devices

Topic	Recommendations
Chairs & stools	Ground and periodically verify ESD protective. Increase periodic compliance verification testing intervals based on actual usage.
Wrist straps	All personnel should use wrist straps connected to a continuous monitoring system (CMS).
Conductive or dissipative floors or floor mats	Use these items in the floor space directly in front of the protected area/workstation (See Figure 2), or in the floor space of other designated protected areas.
Relative Humidity	Keep relative humidity over 40%; monitor and record just before work is started. Additional precautions must be used to operate below 40% RH.
Ionizers	Ionizers should be located at each workstation designated for handling Class 0 devices. The ionizers should be balanced to take into account the most sensitive device handled. The ionizers should be monitored frequently. Check the manufacturer's instructions.
Smocks	Must be grounded to the Common Point Ground or through the wrist strap. However, if a CMS is used, it must not interfere with grounding of the smock or vice versa.
Mating and De-mating cables and harnesses	Must be discharged to ground through an approved method prior to mating and demating to and from ESD sensitive assemblies.
Soldering irons	Check for proper ESD operation before usage. See test parameters in Table 1.
Signage	Display signage identifying designated protected area or workstation for handling Class 0 devices.