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ESD Control Program Periodic Verification

Some practical advice for implementing ESD control periodic checks

Want to accomplish something important? A familiar formula is write a plan, select the specifications, and then periodically test to verify that the plan is being implemented according to the test results. This is basically the requirements of an ESD control program, per the ESD Association standard, ANSI/ESD S20.20. This important standard, entitled *Development of an Electrostatic Discharge Control Program,* covers the requirements necessary to design, establish, implement, and maintain an ESD control program to protect electrical or electronic parts, assemblies and equipment susceptible to ESD damage.

S20.20 is a process document, and provides ESD control plan guidance; one of its requirements is having a "compliance verification plan" as a component of the ESD control plan. Per S20.20, paragraph 6.1.3., Compliance Verification Plan:

> *"A Compliance Verification Plan shall be established to ensure the organization's compliance with the requirements of the Plan. Formal audits or certifications shall be conducted in accordance with a Compliance Verification Plan that identifies the requirements to be verified, and the frequency at which those verifications must occur. Test equipment shall be selected to make measurements of appropriate properties of the technical requirements that are incorporated into the ESD program plan."*

S20.20, paragraph 6.1.3.2., Compliance Verification Plan Guidance, states:

> *"In addition to internal audits, external audits (organization and supplier of ESDS items) should be performed to ensure compliance with planned requirements. Verifications should include routine checks of the Technical Requirements in the Plan. The frequency of verification checks should be based on the control item usage, its durability and associated risk of failure"*

The purpose of this article is to add practical advice on dealing with verification checks, otherwise referred to as periodic testing. Technical requirements and frequency of periodic testing will depend upon the value of the ESD sensitive product, probability of failure, and the potential cost of an ESD induced failure. We will assume adoption of Table 1 in S20.20, listing the minimum recommended technical requirements of ANSI/ESD S20.20, and note typical periodic test frequencies that are currently being practiced in the field. Our advice uses system tests that will provide overall information making periodic testing more effective and productive.

ESD Handbook TR 20.20

S20.20 has an accompanying ESD Handbook, TR 20.20, which offers a comprehensive list of questions (Ref: paragraph 4.3.3, Checklists). However, only general periodic testing frequency advice is offered, as follows:

> ***Worksurface:*** *"Periodic testing of worksurfaces is necessary to evaluate functionality. While not covered specifically in ESD STM-4.1, resistance to ground measurements verify that the path to the equipment grounding conductor is intact. Surface to groundable point [RTG] or point to point resistance [RTT] measurements across the surface are recommended periodically to ensure that excessive wear, dirt, or coatings do not interfere with worksurface function. The frequency of periodic testing is normally specified in corporate operating procedures. However, a common guide would be to conduct these measurements at least quarterly."*

> ***Wrist Strap:*** *"Wrist straps should be tested periodically. The frequency of testing, however, is driven by the amount of risk exposure that can occur between tests. Because wrist straps have a finite life, it is important to develop a test frequency that will guarantee integrity of the system. Typical test programs recommend that wrist straps that are used daily should be tested daily."*

Footwear: *"Once products are found to meet the existing standards, a system test of the footwear in combination with the existing or proposed floor materials in the plant should be made to ensure that the criteria for the facility are met. Incoming inspection on a lot sampling basis should be performed for all static control footwear. In the case of shoes, when the wearer is fitted, the shoe should be tested as worn at the point of acceptance. This is typically done by a resistance test."*

Floor: *"Another consideration is the monitoring requirement to assure that the floor material is still functioning within specifications. The types of monitoring and type of equipment are considerations. In some cases, a simple electrical resistance test with a megohmmeter may suffice. In others, a static charge generation test may be required."*

Seating: *"The recommended electrical resistance range for*

Frequency	ESD Protective Item	Tests*	Specification	Tool/Reference*
Daily	EPA access controlled	Verify that control procedures are being followed	"Access limited to trained or escorted personnel"	Visual ANSI/ESD S20.20
Weekly	ESD protective versions of Insulators	Check areas for presence of non-essential items, particularly insulators Measure charge or RTG of ESD protective product versions	"All nonessential insulators ..must be removed"	Visual Static Field Meter ANSI/ESD S20.20
Quarterly	Signs	EPA has sufficient identification signage EPA boundary marked with aisle tape Workstations have identification signage	"Posted and clearly visible to personnel prior to entry"	Visual ANSI/ESD S20.20
Quarterly	-	For personnel safety, verify that GFCI are installed & personal grounding items not used if exposure to over 250 VAC is possible	"Ground fault circuit interrupters should be considered wherever personnel might come into contact with electrical sources."	Visual ANSI/ESD S20.20
Quarterly	Electrical Ground	Verify correct wiring of 3-wire electrical outlet	"Receptacle wiring should be checked to verify correct wiring configuration"	AC Outlet Analyzer TR 20.20
Quarterly	Worksurface	Measure RTG to equipment ground	10E6 to 10E8 ohms	Megohmmeter Test Kit ESD S4.1 (Work Surfaces)
Quarterly	Seating	Measure RTG to equipment ground	Less than 1 x 10E9 ohms	Megohmmeter Test Kit ESD-STM12.1 (Seating)
Quarterly	Shelves (Mobile or Stationary)	Measure RTG to equipment ground	Less than 1 x 10E9 ohms	Megohmmeter Test Kit ANSI/ESD S20.20 (Table 1)
Quarterly	Flooring-Footwear System	Measure RTG through ESD footwear & person to equipment ground	Less than 3.5E7 ohms	Megohmmeter Test Kit ESD STM 97.1 (Resistance Measurement in Combination with a Person)
Quarterly	Flooring-Footwear System	Approximate voltage on person wearing ESD footwear walking on ESD floor	Less than 100 volts	Charged Plate Analyzer ESD STM 97.1 (Floor Materials and Footwear-Voltage Measurement in Combination with a Person)
Quarterly	Garment	Check for ESD Protective Symbol Measure Sleeve to Sleeve RTT	10E5 to 10E10 ohms	Visual Megohmmeter Test Kit ESD STM2.1 (Garments)
Quarterly	Ionizers	Measure Offset Voltage (Balance) Measure Charge Decay Time	Less than +/- 50 volts 1,000 to 100 volts (< 6 seconds is typically used)	Ionization Test Kit ESD SP3.3 (Periodic Verification of Air Ionizers)
Semi-Annual	Wrist Strap	Measure Breakaway Force (Para. 5.4) Measure Resistance Interior Cuff to plug Run Cord Bending Life Test (Para. 5.7)	>1<5 pounds 0.8E6 to 1.2E6 ohms >16,000 cycles	Force Gage & Fixtures ESD S1.1 (Wrist Straps)
Semi-Annual	Continuous Monitor	Follow manufacturer's instructions	"Constant monitoring devices should be functionally checked periodically to ensure that they are operating as designed."	Manufacturer Calibration or Verification Unit ANSI/ESD S20.20

* Using modified test methods in accordance with concepts outlined in ESD Association standards

Table 1: Typical ESD control plan document

seating is less than 1 x 10E9 ohms as tested in accordance with ESD STM 12.1. This value should be during acceptance testing, installation and periodically thereafter."

Garments: *"To maintain process control, it is imperative that the garment be tested per ESD STM 2.1. The point to point and sleeve to sleeve resistance test should be made."*

Goals

Verification checks or periodic testing should be done with the goal that the ESD control system is functioning properly, so as to provide the company with improved productivity, quality, and customer satisfaction. Keenly important to the ESD coordinator is that these daily, weekly, monthly, quarterly, and semi-annual checks will ensure that the annual ESD audit will be passed with flying colors. This is particularly important if a major customer's contract is dependent upon passing the annual audit, and the consequences of failing such an audit can be drastic.

Typical Periodic Testing Practice

Depending upon the situation, one might test each item or conduct nonrandom sampling looking for worst case conditions. Where a variety of ESD protective products are being used, the user should measure at least one product representative of each type.

Many companies claim that the major benefit to an ESD control program is improving discipline on the shop floor. See our Daily Check Form (Table 2), which can be used to remind workers to control their area and check access, ground at their ESD protected workstation, removal of non-essential items particularly insulators, ESD protective worksurface, ionizers, handling of ESD sensitive part handling , packaging, and that products are used products properly. These checks are in addition to at least daily testing of wrist straps and ESD footwear while worn.

Daily Check Form

Period: week ending _____ Employee / Workstation: _____

Personnel to test Wrist Straps & ESD Footwear, if used, at least daily on a suitable Tester. Results to be logged. This is typically performed at the entrance to the ESD Protected Area

Additional checks to be performed daily by **ALL personnel working in the ESD Protected Area**

Items	Type of Inspections	Date	Date	Date	Date	Date
Access	**Visual Inspection:** Only trained or escorted people in ESD Protected Area					
Ground at ESD Protected Workstation	**Visual Inspection:** Check all grounding cords to see they are connected					
Non-essential items	**Visual Inspection:** Keep work area clear of insulators, particularly insulators including radios, cups, picture frames, regular tape, plastics, regular packaging					
ESD Protective Worksurface	**Visual Inspection:** ESD table mats/laminates cleaned only with ESD Cleaner and free of any tears or breaks.					
Ionizers	**Visual Inspection:** Make sure Ionizers are maintained and air flow directed to products					
ESD sensitive part handling	**Visual Inspection:** Handle un-packaged ESD sensitive items only when grounded					
Packaging	Use ESD packaging including shielding property for shipping or storing ESD sensitive items outside the ESD Protected Area					
Use products properly	**Visual Inspection:** Keep wrist band snug, foot grounder grounding tab in shoe, & ESD Garments buttoned up					

Table 2: Daily ESD check form

Testing is typically performed using a wrist strap/ ESD footwear combo tester located at the entrance to the ESD Protected Area, and results should be logged.

ESD Control Prerequisites

The prerequisites of ESD control are: 1) identifying the ESD Protected Area; 2) identifying all ESD sensitive items; and 3) providing ESD control training.

Signs

A typical periodic testing program would include a quarterly check that the ESD Protected Area is clearly identified using signs (see Figure 1) & aisle tape. (Ref: S20.20, Paragraph 6.2.3.1)

Figure 1: ESD protected area warning sign

ESD Susceptible Items Clearly Identified

ESD Susceptible Items should be clearly identified and handled only in an ESD Protected Area. The ESD susceptibility symbol (see Figure 2) exists to do this (Ref: S20.20, Paragraphs 6.2.3.1 & 6.2.5.1). However, many companies find that it is more cost effective to consider all electronic components and sub-assemblies containing electronic components as ESD sensitive, requiring that ESD precautions be followed when handling. In addition, employees are to be grounded and follow all ESD control procedures while working at an ESD-protected workstation, regardless of what they are working on (even nuts & bolts!). If running different systems dependent upon identifying ESD susceptible items, then periodic verification of this should occur at least quarterly.

Figure 2: The ESD susceptibility symbol

Controlled Access to An ESD Protected Area

Access to an ESD Protected Area is to be controlled. Per S20.20, Paragraph 6.2.3.1, "access to the Protected Area shall be limited to personnel who have completed appropriate ESD training. Trained personnel shall escort untrained individuals while in a Protected Area." This is often accomplished by equipping the entrance to an ESD Protected Area with a wrist strap / ESD footwear combo tester, where test results are logged (Ref: S20.20, paragraph 6.2.2.2). This daily visual verification check should verify that controlled access procedures are being followed.

ESD Control Basics

The basics of ESD control are:

- Ground all conductors
- Remove all non-essential insulators, or convert to ESD protective versions, & neutralize essential insulators with ionizers if the electrostatic charge is considered a threat
- Use low charging and dissipative packaging including static discharge shielding property to store or transport ESD susceptible items outside the ESD protected area

Grounding

Equipment Ground

The most important element of ESD control is to ground all conductors, including people. Personal grounding devices used to ground human beings should be checked daily while being worn. In addition, there are ESD protective product dissipative or conductive versions of common production supplies such as mats, flooring, garments, gloves, chairs, packaging, etc. For example, dissipative loose-leaf binders or document holders can have charges removed from them when handled by grounded personnel or when in contact with a properly grounded ESD worksurface. Since "the third wire (green) AC equipment ground is the preferred choice for ground," the grounding system is dependent upon the electrical outlets being wired properly. This can be easily checked with an AC outlet analyzer. A typical company would verify their electrical receptacles quarterly.

Figure 3: Data logger

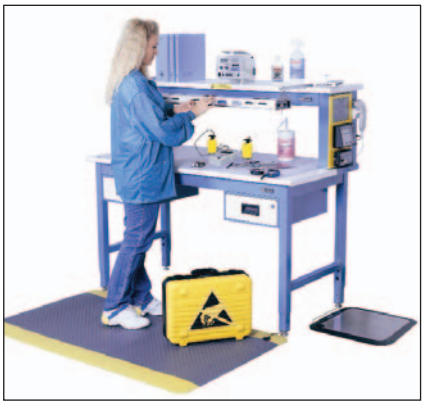

Figure 4: ESD workstation

Worksurface / Floors / Seating / Shelves

The ESD Association standards, primarily used for test lab qualification testing, details RTT and RTG tests where the RTG test is to the mat's groundable snap. Steve Halperin of Stephen Halperin & Associates advises using a three-wire extension cord and measuring RTG to equipment ground. The electrical outlet and the extension cord should be checked to ensure that they are properly wired. Using a surface resistance megohmmeter with one 5# electrode, the sensing lead can be plugged into the extension cord (equipment ground), and then one can move the 5# electrode on many surfaces and quickly take many measurements. We refer to this test as using modified test methods in accordance with concepts outlined in ESD S4.1.

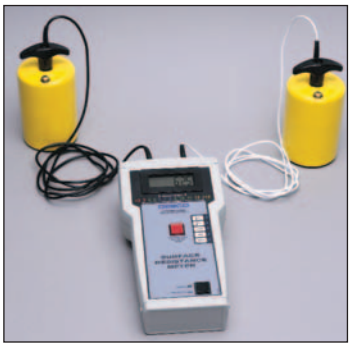

Figure 5: Surface resistance meter

Periodic testing would typically not be performed on every item. Non-random sampling should be used, for example, particularly with worn or dirty worksurfaces, and at least one each of different types should be tested. If the following elements are part of the ESD control program, measuring RTG to equipment ground would include:

- Worksurfaces 1 x 10E6 – less than 1 x 10E9 ohms
- Floors – less than 1 x 10E9 ohms
- Chairs – less than 1 x 10E9 ohms
- Shelves – less than 1 x 10E9 ohms
- Carts – less than 1 x 10E9 ohms

Ideally, particularly if unpackaged ESD sensitive items are placed upon the surface, it should be dissipative with RTG of 1 x 10E6 to less than 1 x 10E9 ohms. Per ESD S4.1, paragraph 8, Resistance Guidelines, "Resistance-to-groundable point 1 x 10E6 to 1 x 10E9 ohms. These guidelines represent a range of resistance that has generally been proven to provide protection in the manufacturing environment."

ESD Handbook, TR20.20, paragraph 5.3.1.7, Electrical Considerations, states:

> *"[RTG is] the most important functional consideration for worksurfaces. This establishes the resistance of the primary path to ground for items, placed on the surface. When worksurface materials are being selected, consideration should be given to possible Charged Device Model (CDM) damage to ESD sensitive products. If CDM damage is a concern then setting a lower resistance limit for the worksurface should be considered. Typically, the lower limit for these types of worksurfaces is 1 X10E6 ohms."*

Resistance Troubleshooting

If the overall resistance RTG to equipment ground measurement is good, this system method provides the information that all the components are good:

- RTT of the surface material
- Snap or other conductor connections to surface material
- Ground cord or other path-to-ground

If the measurement is high, troubleshooting would include measuring each component separately to determine which item is out of spec. The first troubleshooting measurement would typically be RTT of the surface, which can measure high if dirty (as dirt is typically insulative), or coated with silicone from non-ESD cleaners. If surface RTT measures high, it should be re-tested after cleaning with an ESD cleaner and letting the surface dry completely. Ground snaps, common point grounds, and ground cords can be checked for less than 1 ohm resistance using a multimeter. If the ground cord includes a 1 Megohm resistor, the measurement should be 1E6 ohms.

Flooring-Footwear System Resistance in Combination with a Person

The above noted RTG to equipment

ground systems test provides overall information, making periodic testing more effective and productive. Instead of testing program components, it verifies that they are working together properly. Another such systems test is in accordance with ESD STM 97.1, Floor Materials and Footwear - Resistance Measurement in Combination with a Person, which measured the path-to-ground of the ESD floor and ESD footwear and the person together not separately.

Per S20.20, paragraph 6.2.2.2, Personnel Grounding Guidance, "ESD protective flooring, used with approved footwear, may be used as an alternative to the wrist strap system for standing operations." That is, both ESD floor and ESD footwear need to be used together. Personnel will likely be testing their ESD footwear daily, but doing so standing on a metal plate. As part of a quarterly periodic verification plan, we suggest using a Megohmmeter with one lead attached to equipment ground and electrode held by person wearing ESD footwear standing on factory's ESD protective floor measured at 10 volts. RTG should be less than 3.5E7 ohms.

Flooring-Footwear System Voltage Measurement in Combination with a Person

Alternatively, the proper functioning of the flooring-footwear system can be verified by measuring less than 100 Volts on the person in accordance with ESD STM 97.2, where voltage on the person is measured using a charged plate analyzer. A walking pattern is suggested Figure 1 in the standard. However, per Appendix A, "the user of this test method should choose a step pattern typical of the majority of the workers." This test can be approximated using a charged plate analyzer where the electrostatic charge on the person is transferred to the conductive plate clipping worn wrist strap cord to the plate. The charged plate analyzer will measure the charge on a person wearing ESD footwear walking upon ESD Floor taking a few normal steps.

ESD Protective Product Version of Insulators

ESD workstations should be checked to verify that all non-essential insulators are removed. Ideally, all ESD protective items are marked or identified. A grounded static field meter should be used to measure the ability of questionable items to generate a charge. Per S20.20, "all nonessential insulators, such as those made of plastics and paper (e.g. coffee cups, food wrappers and personal items) must be removed from the workstation." Instead of removing them altogether, many insulative items are replaced with ESD protective versions which will be low charging, conductive/dissipative, or both. These include ESD protective packaging, material handling containers, tape, document holders, loose leaf binders, etc. The worksurface RTG test can be repeated with the 5# electrode placed upon the dissipative ESD protective item, verifying a path-to-ground.

Per ESD Handbook, TR 20.20, paragraph 2.4:

> *"It should be understood that any object, item, material or person could be a source of static electricity in the work environment. Removal of unnecessary nonconductors, replacing nonconductive materials with dissipative or conductive materials and grounding all conductors are the principle methods of controlling static electricity in the workplace, regardless of the activity."*

Garments

ESD garments are not required by S20.20, but can be an effective means of complying with Paragraph 6.2.3.2, Protected Areas Guidance. "All process essential insulators that have electrostatic fields that exceed 2,000 volts should be kept at a minimum distance of 12 inches from ESDS items," since worker clothing may charge to that level and beyond.

An ESD garment is manufactured from a number of panels, which must have electrical continuity. Garments whose electrical continuity wears out over time can do more harm than good. Per ESD Handbook, TR 20.20, paragraph 5.3.13.2.6, Proper Use, "the garment should be electrically bonded to the grounding system of the wearer so as not to act as a floating [conductor]." If not grounded or if a conductive panel is electrically isolated, the garment can become an isolated charged conductor that can discharge to ESD sensitive items.

To verify point-to-point RTT of 10E5 to 10E10 ohms, the garment should be placed on an insulative test surface. Place a 5# electrode on each sleeve, and measure resistance using a Megohmmeter. The sleeve to sleeve resistance test can be made using a "banker's clip" on each sleeve and isolating the

garment by hanging it in air (a wooden hanger can also be used). Connect Megohmmeter leads to banker's clip via alligator clip or bulldog clip. This verification should be done quarterly.

Ionizers

Ionizers are pieces of equipment that can also do more harm than good if not properly maintained. Insulators cannot be grounded (non-conductors by definition). Ionizers neutralize electrostatic charges with fans that blow large quantities of negatively and positively charged ions. The quantity of negative and positive ions cannot be exactly the same. Measured in volts, the difference is referred to as balance or offset voltage. If significantly out-of-balance, the ionizer can place a significant charge on items instead of neutralizing charges.

Per ANSI/ESD S20.20, Paragraph 6.2.3.1, Protected Areas Requirement, "ionization or other charge mitigating techniques shall be used at the workstation to neutralize electrostatic fields on all process essential insulators if the electrostatic field is considered a threat."

An ionization test kit, in accordance with ESD SP3.3, Periodic Verification of Air Ionizers, can very quickly verify the proper functioning of an ionizer. The ionization test kit should be grounded and placed in the ionizer airflow to measure the balance (offset voltage). Just place a 1,000 volt charge on its isolated plate and place the ionization test kit on a worksurface. Count or use a stopwatch to measure charge decay time until the charge is reduced to 100 volts. This should be done with both a positive and a negative 1,000 charge on the isolated plate. A six second charge decay time requirement is not unusual, and the S20.20-recommended technical requirement range is < +/- 50 volts voltage offset. Many users perform this periodic test quarterly and/or whenever the ionizer emitter pins are cleaned.

Wrist Straps

Most companies will have workers test their wrist straps while being worn daily. Per ESD-S1.1, paragraph 6.1.3, Frequency of Functional Testing, "the wrist strap system should be tested daily to ensure proper electrical value." However, two important wrist strap test should be performed periodically, perhaps semi-annually; the "breakaway force" test and the "bending life" test.

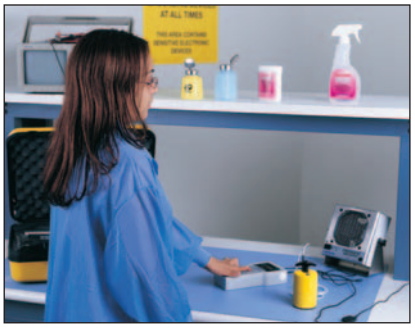

Figure 6: ESD mat with test kit

For ESD control, to prevent accidental disconnects, a strain gage or torque meter can be used to verify the ESD S.1 breakaway force requirement of greater than one pound. The less than five pound requirement can be an important safety issue.

Per ESD Handbook, TR 20.20, paragraph 5.3.2.2.1.1, Cuffs:

> *"Wrist strap cuffs may have a quick parting electrical-mechanical connector that mates with a corresponding connector on the head of the ground cord. This connector serves two purposes. First, it is a physical connection for attaching the ground cord. Second, it is the groundable point on the cuff. Quick release is an important feature of the connector. The breakaway force should be low enough to allow easy release, but high enough to prevent unintentional disconnection. If the breakaway force is too light, the ground connection could be lost without the knowledge of the wearer."*

Per ESD Handbook, TR20.20, paragraph 5.3.2.2.2, Wrist Strap Ground Cord:

> *"At first glance, the ground cord appears to be a relatively simple*

assembly. However, the design requirements are considerable, given the wide range of user applications and the durability requirements of constant tugging, flexing, and dragging over the edge of workstation tops and equipment chassis."

To ensure reliable circuit connections, the bending life test found in paragraph 5.7 applies, using the apparatus described in ESD S1.1. Many companies consider the 16,000 cycles figure found in ESD S.1 totally inadequate as most good quality wrist strap cords will operate a million cycles or many times that. Instead of part of their periodic testing, some companies require the breakaway force and bending life test wrist strap test information to be provided by their suppliers.

Continuous Monitors

If used, continuous monitor functions can be quickly verified at the workstation as leading manufacturers have calibration or verification units available. Frequency of the periodic test might be done semi-annually. Continuous monitors are becoming increasing important as a cost effective means to verify on an ongoing basis that operator and worksurface ESD controls are functioning properly. Per the ESD Handbook, "if the products that are being produced are of such value that knowledge of a continuous, reliable ground is needed, and then continuous monitoring should be considered or even required." (Ref: TR 20.20, paragraph 5.3.2.4.4.)

Most companies will check their continuous monitors semi-annually. Following manufacturer's instructions, this can be accomplished within a minute without removing the monitor from the workbench.

Conclusion

An ESD control program should be treated as an on-going process, like any good quality control system. As such, it should never be treated as an event. The ESD control plan compliance verification plan must include ongoing and effective periodic or verification checks. Issues will be identified which can be corrected, greatly improving the probability of passing annual audits.

ESD control programs must be comprehensive and ESD protective products must be checked periodically to verify that they are working properly. If used effectively, companies can turn ESD control programs into a competitive advantage - a strategic tool focused on quality, productivity, and customer satisfaction improvement. ■

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References

1. ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), ESD Association, 1999.
2. ESD TR 20.20, Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment
3. ANSI/ESD S1.1: Wrist Straps.
4. ANSI/ESD STM2.1: Garments
5. ESD SP3.3: Periodic Verification of Air Ionizers.
6. ANSI/ESD S4.1: Worksurfaces – Resistance Measurements
7. ESD STM7.1: Resistive Characterization of Materials — Floor Materials
8. ANSI/ESD STM12.1: Seating - Resistive Measurement
9. ANSI/ESD STM97.1: Floor Materials and Footwear – Resistance Measurement in Combination with a Person.
10. ANSI/ESD STM97.2: Floor Materials and Footwear – Voltage Measurement in Combination with a Person.