ESD Association Standard Practice

ANSI/ESD SP10.1-2007

ANSI/ESD SP10.1-2007

Reaffirmation of ESD SP10.1-2000

For the Protection of Electrostatic Discharge Susceptible Items-

Automated Handling Equipment (AHE)

Electrostatic Discharge Association
7900 Turin Road, Bldg 3
Rome, NY 13440-2069

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Approved November 30, 2007

ESD ASSOCIATION ®

ESD Association Standard Practice for the Protection of Electrostatic Discharge Susceptible Items –

Automated Handling Equipment (AHE)

Approved June 24, 2007
ESD Association, Inc.

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FOREWORD

Recent years have witnessed an increasing use of automation in the electronics industry. There is hardly a device, circuit board, or assembly that does not undergo one or more types of automated handling at some point during its production cycle. Further, circuit density for most semiconductor devices has steadily increased, leading to a higher ESD susceptibility for some semiconductor devices. As a result, extensive measures are required to protect these sensitive devices during manufacture.

Many of the same methods used to deal with static charge on a workbench have been applied to automated handling equipment. Grounding, the use of static dissipative materials, and ionization are techniques commonly used to deal with static charge. Automated handling equipment presents additional problems for effective static control. Devices may become polarized by an electric field, or charge can be induced onto a device that is grounded in the presence of the electrostatic field. Also, a charge can be generated by contact with or separation from various materials. Components of automatic handling equipment (AHE), particularly when integral with thermal chambers, generally require the use of easily charged materials. Grounding of sliding or rotating components may also be a challenge. These are some common problems encountered by both manufacturers and users of automated equipment. ESD control methods should be verified periodically. Test methods are needed to insure grounding integrity and verify that product does not acquire an unacceptable level of static charge during its passage through automated equipment.

In order to achieve suitable ESD control in automated handling equipment, it may be necessary to monitor or verify electrostatic charge on product as it passes through the equipment. This can provide both continuous verification of ESD counter-measures and a method for locating sources of charge generation.

Various types of measuring devices have been developed to determine the electrostatic potential or estimate the charge on product as it passes through the equipment. In order to verify the performance of these measuring devices, it is necessary to have a means of testing their repeatability and calibration, both at manufacture and periodically during service. This standard practice has been developed to assist in the generation of meaningful, repeatable data using these measuring devices.

The diverse range of handling equipment, environments, and device sensitivities may require modifications to the test apparatus described in this standard practice. Further, the test conditions and results given within this standard practice may not always represent acceptable performance. Specifications should be agreed upon between the user and manufacturer of the automatic handling equipment in each application.

This document was originally designated ESD SP10.1-2000 and was approved on February 6, 2000. ANSI/ESD SP10.1-2007 is a reaffirmation of ESD SP10.1-2000 and was approved on June 27, 2007.

At the time ANSI/ESD SP10.1-2007 was approved, the 10.0 Handlers Subcommittee had the following members:

Don Boehm Dou Yee Enterprises	Donn Bellmore, Chair Universal Instruments Corp.	Jay Hamlin Medtronic
Vladimir Draz 3M	Rejean Dion Bystat International, Inc.	Arnold Steinman MKS, Ion Systems
David Swenson Affinity Static Control Consulting, LLC	Donald Pritchard Monroe Electronics	Julius Turangan Western Digital

At the time the ESD SP10.1-2000 version was approved, the 10.0 Handlers Subcommittee had the following members:

Joseph Bernier, Chair Intersil		Craig Zander, Secretary Restronics Company, Inc.
Thomas Albano Eastman Kodak Company	Donn Bellmore Universal Instruments	Donald Boehm Novx Corporation
Ken Hansen Tellabs	John Kinnear IBM	Thomas Mohler Raytheon Systems
Charles Perry Monroe Electronics	Donald Pritchard Trek, Inc.	Arnold Steinman Ion Systems

The following individuals made significant contributions to this document:

Wayne Tan Advanced Micro Devices	Rita Shartzer Motorola

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1.0 PURPOSE, SCOPE, AND APPLICATION

1.1 Purpose

This standard practice provides test procedures for evaluating the electrostatic environment associated with automated handling equipment.

This document provides testing and data reporting procedures for the evaluation of ESD ground integrity in automated handling equipment (AHE) and for the evaluation of charge generation and accumulation on devices in AHE. These methods qualify newly installed and existing equipment by verifying the equipment's existing ground paths and by determining that charge on ESD sensitive devices can be detected.

1.2 Scope

This standard practice covers resistance-to-ground of machine components and sources of charge in automated handling equipment.

This method will not measure charge directly but indirectly by measuring the voltage or field associated with the charge.

In particular, it establishes test procedures for:

- the measurement of DC electrical resistance between machine components of AHE and the equipment grounding conductor (EGC). See Annex A.
- testing AHE to determine whether charge is being generated on devices as they move through the equipment
- reporting the correlation between measured voltages and known test voltages as they apply to AHE. (Charge measuring devices are not addressed in this document.)

Grounding methods and materials specified herein may or may not provide adequate grounding for conditions other than steady state DC. Reactance considerations at any frequency are beyond the scope of this document. In addition, this standard practice does not determine the effectiveness of any grounding method for reducing electromagnetic interference (EMI). Explosive, ordnance, or flammable materials handling considerations are also excluded from this standard practice.

1.3 Application

Test procedures contained within this standard practice may be used by both AHE manufacturers and users to produce repeatable data describing the ground integrity of AHE and the charge generated and accumulated on specific package types during normal operating usage of the AHE. Since there is a wide variety of device sensitivities, AHE types, package types and environmental conditions, users and manufacturers are strongly urged to agree upon appropriate specifications, measurement accuracies, modifications or additions to the tests described herein. This standard practice relies upon point-to-point DC resistance measurements taken from machine components of concern or the equipment chassis to the EGC.

2.0 NORMATIVE REFERENCES

Unless otherwise specified, the following documents of the latest issue, revision or amendment form a part of this standard to the extent specified herein:

ESD ADV1.0, ESD Association Glossary of Terms[1]

ANSI/ESD S6.1, Grounding[1]

ANSI/ESD S1.1, Wrist Straps[1]

ANSI/NFPA-70, National Electric Code[2]

3.0 DEFINITIONS

The following definitions are in addition to those found in ESD ADV1.0, ESD Association Glossary of Terms:

Automated Handling Equipment (AHE). Any form of self-sequencing machinery that manipulates or transports product in any form; e.g. wafers, packaged devices, paper, textiles, etc.

Energized. The state of a piece of equipment such that it carries electrical, fluid, thermal, mechanical or other form of energy in a state which could pose a hazard to personnel.

Critical Path Components. Any portion of the AHE within a certain distance of the device path. That distance should be agreed upon between the manufacturer and end user. See Annex A for suggested parameters.

Device Path. The route traveled by a device in an AHE.

Device. Product being processed by AHE (e.g. an integrated circuit [IC] or a printed circuit [PC] board).

Correlation Sample. A representative device used for correlating measured voltages with known applied voltages.

4.0 SAFETY REQUIREMENTS

4.1 Electrical – General

4.1.1 The procedures and equipment described in this document may expose personnel to hazardous electrical conditions. Users of this document are responsible for selecting equipment that complies with applicable laws, regulatory codes and external and internal policy. Users are cautioned that this document cannot replace or supercede any requirements for personnel safety. The ultimate responsibility for personnel safety resides with the end user of this document. A thorough understanding of machine operation, capabilities, and potential hazards is imperative before any testing may commence. Furthermore, care and forethought should be taken to prevent injury from moving machine components Resistance values obtained by methods described in this document should not be used to set limits for electrical hazards to personnel.

[1] ESD Association, 7900 Turin Rd, Bldg. 3, Rome, NY 13440-2069, 315-339-6937
[2] American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103-1187, 215-299-5400

4.1.2 Ground Fault Circuit Interrupters (GFCI) and other safety protection should be considered wherever personnel might come into contact with electrical utlility sources.

4.1.3 Electrical hazard reduction practices should be exercised and proper grounding instructions for the equipment must be followed when performing these tests.

4.2 Electrical – Automatic Handling Equipment

4.2.1 AHE may include electrical equipment which can pose severe dangers to personnel when energized. High voltage electrical hazard practices should be exercised at all times when performing tests on such equipment.

4.2.2 AHE being tested under the test methods of this standard practice must be properly grounded per the manufacturer's specifications, the National Electric Code (ANSI/NFPA-70) and any applicable local codes.

4.2.3 The AHE should be disconnected by a lockout/tagout, by switching off via the appropriate service equipment or by disconnecting the power plug at the utility outlet. The power may be energized for a short period, when absolutely necessary, for testing purposes.

4.3 Environmental

Since some types of AHE have integral environmental thermal chambers, care must be taken to protect personnel from thermal injury (i.e. burns or frostbite) as well as damage to test equipment. Care must be taken by the user to be fully aware of the operating environment involved and the capabilities of the test equipment in use.

5.0 MEASUREMENT EQUIPMENT

5.1 Resistance Measurements – Apparatus

5.1.1 Continuity measurements of 1 megohm or less shall be made with an instrument capable of measuring a resistance of 0.1 ohm through 1 megohm with an accuracy of ± 10% of the value being measured.

5.1.2 The meter shall have an open circuit voltage of 100 volts (± 5%) for measurements of 1.0×10^6 ohms and above, and 10 volts (± 5%) for measurements less than 1.0×10^6 ohms. The meter must be capable of making measurements from 1.0×10^5 ohms to 1.0×10^{11} ohms.

5.1.3 Applicable probes should be selected by the user.

When making measurements on soft surfaces (e.g., belts, flexible thermal insulation, or many static dissipative surfaces), care must be taken to prevent damage to these surfaces. Conductive elastomers can be used as probes for soft surfaces to avoid physical or cosmetic damage to those surfaces.

NOTE: The force applied to the probes may affect the reading and may damage the surface of the item being measured. Use only enough force to obtain a stable reading.

5.2 Charge Accumulation Measurements

5.2.1 It is often not practical to measure charge directly. Therefore, charge is often evaluated indirectly by evaluating the electric field or the voltage that results from the charge. This section describes charge evaluation using a voltage sensor (electrostatic voltmeter) to measure the voltage associated with a given charge. A voltage measurement was selected over an electric field strength measurement because electrostatic voltmeters offer higher response speeds and can resolve smaller surface areas/devices than can conventional fieldmeters.

5.2.2 Use a voltage sensor such as an electrostatic voltmeter with a response speed and sampling rate fast enough to detect the electrostatic potential on a device moving at the fastest operational speed achieved in the AHE to be measured. The voltage sensor shall have an output that can be monitored by data logging equipment (see 5.2.4). See Annex B for recommendations on selection of electrostatic voltmeters.

5.2.3 Use an appropriate probe for the voltage sensor described in 5.2.2. The probe must be able to detect the electrostatic potential on the smallest device to be tested. See Annex C for recommendations on installation of the voltage sensor.

5.2.4 Use a Storage Oscilloscope or equivalent data logging equipment capable of capturing and displaying the signal from the instrument described in 5.2.2.

5.2.5 Use a DC Voltage Supply capable of 500V. For safe operation of the power supply, refer to the manufacturer's equipment manual.

6.0 TEST PROCEDURES – RESISTANCE MEASUREMENTS

This section defines test methods for measuring point-to-point resistance between various critical locations on AHE.

6.1 Test Preparations

6.1.1 Before making measurements, clean the machine components to be measured in accordance with the manufacturer's recommendations.

6.1.2 Clean all electrodes to be used in the tests with a solution containing 70% isopropyl alcohol and 30% deionized water applied with a lint-free tissue or swab.

6.1.3 The AHE and all probes shall be in their normal operating environment (i.e., temperature and humidity) for a minimum of 24 hours preceding any testing.
NOTE: Minimum humidity conditions usually result in the highest resistance readings.

6.2 Test Data Reporting

6.2.1 General Information

6.2.1.1 Report the AHE manufacturer's name, model #, and serial #. (Refer to Annex D – Sample Data Sheet).

6.2.1.2 Report the date of test, person(s) performing the tests (names), ambient temperature and relative humidity.

6.2.1.3 Report the manufacturer's name, model #, serial #, and calibration date of all test equipment used during testing, including the type of probe used.

6.2.1.4 Report all application specific information such as rotational rate (e.g. revolutions per minute) of rotary components, temperature of any mechanisms tested within a thermal environment, and any other particulars deemed necessary.

6.2.2 Required Measurements

6.2.2.1 Short the probes of the resistance meter together. Record the short circuit resistance in ohms. (See sample data sheet in Annex D).

6.2.2.2 Measure and record the resistance between the ground point on the equipment chassis and the ground point at the end of the equipment's power cord. If a separate connection is made from the ground point on the equipment chassis to the EGC or other ground point, measure this resistance instead. (See ANSI/ESD S6.1.)

6.2.2.3 Measure and record the resistance between the ground point on the equipment chassis and all designated ESD ground points.

6.2.2.4 Measure and record the resistance between critical path components and the ground point on the equipment chassis (see Annex A). Critical path components may be separated from ground by moveable components. In this case, measure the resistance-to-ground at multiple locations throughout the range of travel.

6.2.2.5 Different applied voltages can result in significant variation in measured resistance. If handling devices with known Charged Device Model (CDM) sensitivities of 100V or less, consider repeating the measurements of resistances greater than 1 megohm with a 10V applied voltage instead of the 100V specified in 5.1.2.

7.0 TEST PROCEDURES – CHARGE ACCUMULATION MEASUREMENT

7.1 Test Preparations

7.1.1 It is often not practical to measure charge directly. Therefore, charge will be evaluated using a voltage sensor (electrostatic voltmeter) to measure the voltage associated with a given charge.

7.1.2 For a fixed amount of charge, the voltage on a device changes (inversely) with its proximity to ground. During the measurement process the positions of the device, the voltage sensor, and ground should be fixed.

7.1.3 Install the voltage or electrostatic field sensor using Annex C for guidance.

7.1.4 During all testing, test personnel within 2 meters (6.7 feet) of the AHE should be properly grounded to the same potential as the machine under test. Reference ANSI/ESD S1.1.

7.1.5 Before making any measurements, the AHE to be evaluated should be cleaned in accordance with the manufacturer's recommendations.

7.1.6 The AHE and all probes shall be in their normal operating environment (i.e. temperature and humidity) for a minimum of 24 hours preceding any testing.

NOTE: Minimum humidity conditions usually result in the highest charge readings.

7.2 Measurement Correlation

This procedure establishes the relationship between a known voltage applied to a device and the voltage measured on the device as it passes through the AHE. The following sections provide methods applicable to small devices such as IC's and larger devices, such as PC boards.

7.2.1 Correlation Sample – Integrated Circuit

7.2.1.1 Select a representative device to be measured.

7.2.1.2 Attach conductive material, such as aluminum foil, to the surface of the device to be measured. Keep to the same size and shape as surface to be measured in actual AHE. Isolate the conductive material from any grounded or dissipative surface.

NOTE: Some ICs have the case/lid connected to a ground pin.

7.2.1.3 Turn off any ionizers that may be operating in the vicinity.

7.2.1.4 Apply 500V ± 10% to the conductive material, referenced to the third wire safety ground (EGC).

7.2.1.5 Position the probe over the device and adjust spacing for the maximum reading or to the manufacturer's specified spacing. Record spacing and orientation as well as the voltage reading.

NOTE: A maximum reading lower than the applied voltage may be an indication that the instrumentation's probe aperture is too large for the size of the device being measured. (See Annex B.) Also, be aware that the voltage on the test device may decay over time due to its resistance to ground or due to surface contamination. The voltage reading should be made before this effect is of appreciable magnitude, for example, less than 10%) Caution: Electrostatic voltmeter probes have a voltage on the probe that is shown on the voltmeter display.

7.2.1.6 Record the voltage measurements, spacing, and location for each probe position that will be used in measuring devices on the AHE. NOTE: The ratio of the measured voltage to the applied voltage (for a known spacing) is important. It will allow calculations from later measurements in 7.3 to help determine the apparent voltage present on the device measured.

7.2.1.7 Turn on any ionizers that were turned off in 7.2.1.3

7.2.2. Correlation Sample – PC Board

7.2.2.1 Select a sample of the product to be monitored – populated or unpopulated.

7.2.2.2 Attach conductive material, such as aluminum foil to the surface to be measured. Keep to same size and shape as surface to be measured in actual AHE (e.g. make a rectangle out of foil the same size as one of the devices on the production PC board). Isolate the conductive material from any grounded or dissipative surface.

NOTE: Some ICs have the case/lid connected to a ground pin.

7.2.2.3 Follow procedure of 7.2.1.3 to 7.2.1.7.

7.2.3. Correlation Testing

7.2.3.1 Run the AHE in normal operating mode.

7.2.3.2 Use the correlation sample from 7.2.1.2 or 7.2.2.2

7.2.3.3 Turn off any ionizers that may be operating in the vicinity.

7.2.3.4 Apply 500V +/- 10% to the conductive material, referenced to the third wire safety ground (EGC).

7.2.3.5 Make sure the probe is in the same orientation and has the same spacing as recorded in 7.2.1.5.

7.2.3.6 Connect and setup the storage oscilloscope to capture the voltmeter output waveform for the charged device that will pass by the probe. Pass the device or board through the AHE and capture the waveform.

7.2.3.7 Compare the peak voltage of the captured waveform to the applied voltage and to the voltages recorded in 7.2.1.6.

7.2.3.8 Turn on any ionizers that were turned off in 7.2.3.3

7.3 Test Data Reporting

7.3.1. General Information

7.3.1.1 Report the make, model and serial number of the AHE under test as well as the product number and package style that was used for these tests.

7.3.1.2 Report the date, person(s) performing the tests, ambient temperature and relative humidity.

7.3.1.3 Report the operating temperature of the AHE during these tests if different than ambient.

7.3.1.4 Report the make, model and serial number of all test equipment used during the test.

7.3.1.5 Report any other condition deemed important.

7.4 Measuring Devices on the AHE

7.4.1 Using the voltage or electrostatic field sensor correlated in 7.2, measure the voltage on actual devices moving through the AHE. Make sure to use the same spacing from the probe to the surface of the measured device as was used in the correlation of 7.2. If different spacing is required at various locations in the AHE, repeat 7.2 for each desired spacing.

7.4.2 Take measurements at various stages of the device path through the AHE, recording the locations measured and the voltage or electrostatic field sensor's readings. See Annex D for an example test data sheet.

NOTE: For PC boards, measure various devices on the board as it passes through the AHE, especially those devices known to be sensitive to low levels of ESD. See Annex C for information on locations to be measured.

ANNEX A (INFORMATIVE): SUGGESTED EQUIPMENT GROUNDING GUIDELINES

The following are suggested guidelines for AHE design, construction and testing.

- All stationary/fixed conductive machine elements within 15 cm (6 inches) of a device's critical path should be grounded to the machine chassis within 1.0 ohm*
- All insulative materials within 15 cm (6 inches) of a device's critical path should be shielded, coated, plated, or otherwise rendered static safe.

NOTE: With today's technology, many plastics can be made dissipative with the addition of suitable compounds, and can then be grounded.

- All static dissipative materials within 15 cm (6 inches) of static sensitive devices should be grounded.
- Equipment that handles sensitive devices should have designated operator ground point(s).
- Where possible, all machine components that contact device leads should be static dissipative and grounded so as to prevent CDM (charged device model) type damage.
- Where possible, all machine components separated from the chassis by bearings of any kind (solid, rolling, radial linear, etc.) should be grounded in a manner that will provide a constant ground path (1 megohm or less) regardless of rotary or transitional rate. This may include but is not limited to: flexible ground conductors (i.e. braided cables), metal brushes, graphite commutators, beryllium copper commutators, conductive greases, etc. Measurements of continuity on these assemblies when idle or powered-down may not take into account intermittent connections of moving parts.
- Any surfaces on which operators may be prone to place devices should be static dissipative and grounded.
- Pneumatic and electrical lines should be constrained in order to minimize rubbing (and hence tribocharging) between themselves and other machine components.
- Pneumatic lines operating in close proximity (15 cm [6 inches]) to product should be conductive or static dissipative and grounded, wherever possible. Otherwise, they should be shielded and grounded using braided shielding.
- Wire bundles in close proximity (15 cm [6 inches]) to product should be shielded and grounded using braided shielding.
- Device pick-up mechanisms such as vacuum cups, nozzles and grippers should be conductive or static dissipative and grounded. Pick-up mechanisms contacting devices should do so with a minimal contact area and velocity, within reason, in order to minimize tribocharging on device packages.
- Designated ESD ground points should all be directly connected to the EGC, with a resistance of 1.0 ohm[1] or less.
- Where possible, all machine conductors (wires and components) which are relied upon to provide a ground path, shall be connected to the machine's EGC in a manner which will provide sufficient strength such that it may not be inadvertently disconnected. ESD ground path conductors should be braided wire where possible.
- For anodized surfaces - insure that the underlying conductive substrate is connected to the EGC.

*1.0 ohm is considered a realistic guideline but may not be satisfactory for high current operation modes (e.g., motors) or fault modes (shorts to chassis components)—lower resistance connections may be necessary to limit voltages to acceptable levels.

ANNEX B (INFORMATIVE): SELECTION OF ELECTROSTATIC VOLTMETERS

The important considerations for selecting an electrostatic voltmeter are:

1. the required electrostatic voltage measurement range;
2. the required measurement response time;
3. the required measurement accuracy;
4. the spatial resolution.

1. The electrostatic voltmeter should have voltage ranges consistent with the anticipated levels of charge on surfaces or devices being processed by the AHE. A selection of too high a measurement range may sacrifice voltage resolution at the low end of the range due to noise, while selection of too low of a measurement range may cause out-of-range-operation (saturation).

2. The required response time of the electrostatic voltmeter must be carefully selected in applications where (a) surfaces with different voltage levels are rapidly scanned by moving the electrostatic voltmeter probe across the surfaces, or (b) where charged devices are moving quickly past the probe. For full measurement accuracy, the electrostatic voltmeter needs to have a response time (10% to 90%) that is four times faster than the time period that the surface / device is under the probe.

   Example: If the time from the leading edge of the device passing under the probe until the trailing edge of the device passing under the probe is 12 milliseconds, then the electrostatic voltmeter should have a response time of 3 milliseconds or faster.

3. The accuracy of an electrostatic voltmeter measurement is dependent on factors such as:

   A. The spacing distance between the measured surface and the probe;

      In general, if the probe's sensing electrode aperture is distance D (e.g., 2 mm) away from the surface / device, the probe will resolve an area on the surface that is approximately 5D (e.g., 10 mm) in diameter.

   B. The presence of electrostatic fields from extraneous charge sources (not related to the surface/device) to the probe.

      Keeping the probe very close to the surface-under-test during a measurement significantly limits the effects of extraneous electrostatic fields on the accuracy of the measurement.

   C. The size and geometry of the measured surface / device in relation to the size and geometry of the probe's sensing electrode aperture

Reference the equipment manufacturer for more information.

ANNEX C (INFORMATIVE): RECOMMENDATIONS ON INSTALLATION OF THE VOLTAGE OR ELECTROSTATIC FIELD SENSOR

NOTE: Due to the specialized measurement needs at various locations in AHE, only general requirements for the installation of charge measuring apparatus will be given in this section.

The general recommendations on locations of the sensors are where the device is separated from a surface and where a device is placed on a conductive surface. In a typical IC handler such places are:

1. When a device is lifted from the input tray
2. When a device is placed on or lifted from input shuttle
3. When a device is placed on the test socket
4. When a device is placed on or lifted from exit shuttle
5. When a device is placed on exit tray
6. When a device is tested with the test head

The following diagram is intended only as an example to illustrate some of the areas that should be measured.

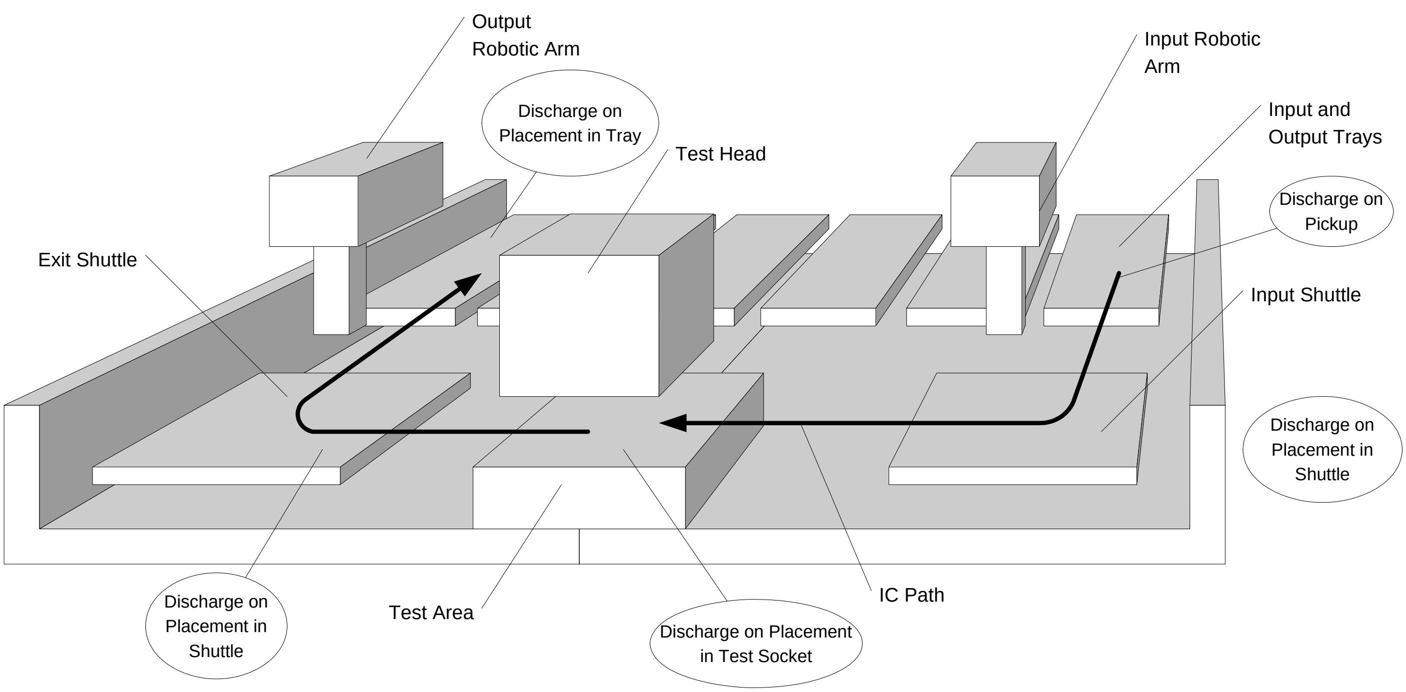

Figure 1: Example of Measurement Points on an Automated Handler

ANNEX D (INFORMATIVE): SAMPLE DATA SHEET

Equipment ESD Evaluation

General Information

Equipment Name / ID:	Date of Test:
Model #:	Ambient Temp (C°):
Manufacturer:	Relative Humidity (%RH):
Serial #:	Test Technician Name:
Application Specific Notes:	
Test Equipment: Name Model # Serial # Cal. Date	Comments

Test Results - Resistance Measurements

Short Circuit Resistance:		Ohms:	
Primary Ground To:			
Description	Measured Voltage	Max. Allowed Voltage	Comments
Notes:			

ANNEX E (INFORMATIVE): SAMPLE TEST REPORT FORM

Equipment ESD Evaluation

General Information

Equipment Name / ID:				Date of Test:	
Model #:				Ambient Temp (C°):	
Manufacturer:				Relative Humidity (%RH):	
Serial #:				Test Technician Name:	
Application Specific Notes:					
Test Equipment: Name	Model	Serial #	Cal. Date	Comments	
Device Packaging and Material Description:					

Test Results — Voltage or Electrostatic Field Measurements

Max. voltage with 500V applied to correlation device (stationary): ____________V

Voltage measured with 500V applied to correlation device in operating AHE: ____________V

Location	Measured Voltage	Max. Allowed Voltage	Comments

Notes:

ANNEX F (INFORMATIVE): BIBLIOGRAPHY

ANSI/RIA R15.06, American National Standard for Industrial Robots and Robotic Systems - Safety Requirements

SEMI E7-91, Specification for Electrical Interfaces for the U.S. Only