MATERIAL EVALUATION REPORT

STATIC DECAY, RESISTANCE AND TRIBOELECTRIC CHARGE GENERATION TESTING OF MERINO ESD LAMINATE SAMPLES

MERINO INDUSTRIES, INC.

JUNE 6, 2011

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GENERAL

Electrostatic characterization tests were performed by the ETS Testing Laboratory on Merino ESD Laminate samples submitted by Merino Industries, Inc. Six (6) samples were tested for static decay, resistance and triboelectric charge generation compliance.

TEST CONDITIONS

Static Decay

12% Relative Humidity	
Date of Test:	5/12/11
Humidity:	12.1% RH
Temperature:	74°F
Conditioning Time:	50 Hours
50% Relative Humidity	
Date of Test:	5/17/11
Humidity:	50.0% RH
Temperature:	74°F
Conditioning Time:	92 Hours

Point-to-Point and Point-to-Ground Resistance

12% Relative Humidity	
Date of Test:	5/20/11, 6/6/11
Humidity:	11.8 & 12.3% RH
Temperature:	72-76 °F
Conditioning Time:	50 Hours
50% Relative Humidity	
Date of Test:	5/23/11
Humidity:	50.1% RH
Temperature:	72°F
Conditioning Time:	66 Hours

Charge Generation

12% Relative Humidity	
Date of Test:	5/17/11
Humidity:	12.0% RH
Temperature:	74°F
Conditioning Time:	89 Hours

TEST APPARATUS

HUMIDITY CONTROL

When performing static decay and charge generation testing an ETS Series 5000 Controller and 5500 Chamber are used to provide the controlled environment to condition and test the samples at the specified relative humidity. The system is capable of controlling the humidity to within 1% of the desired level with an accuracy of ±2% RH and is calibrated to standards traceable to NIST. When performing resistance testing the ETS Controlled Environment Room is used to condition and test the samples at the specified conditions. The control system is capable of controlling the humidity to within 1% of the desired set point with an accuracy of ±2% R.H. and temperature to within ±2°C.

STATIC DECAY

An ETS Model 406 Static Decay Meter is used to perform static decay measurements. A System Test Module (STM) is used to verify the calibration of the Static Decay Meter.

RESISTANCE

Resistance measurements between two points or between a point and groundable point are performed using a Dr. Thiedig Milli-TO-2, or an ETS Model 871 Wide Range Resistance Meter and two ETS Model 850 Surface Resistance Probes.

TRIBOELECTRIC CHARGE EVALUATION

The evaluation of the relative triboelectric charging characteristics of planer material is performed using an ETS Model 236 Inclined Plane Triboelectric Charge Test System. This system utilizes an inclined plane set at 15°, 1" long x 1" dia. Quartz and Teflon cylinders and an ETS Model 230 Nanocoulombmeter with 3.25-inch Model 231 Faraday cup and footswitch. An Aerostat bench ionizer is used to neutralize the charge on the cylinders prior to test.

TEST METHODS

STATIC DECAY

Static decay testing is based on the test method described in Mil-Std-3010, Method 4046 "Electrostatic Properties of Materials". This test method requires a 3 x 5-inch test specimen be placed between a pair of electrodes electrically connected together and be conductively charged to both plus and minus 5000 volts. After the sample has accepted the applied charge, the charging voltage is removed, the electrodes are grounded and the time for the charge to bleed down to a specified cutoff level is measured. This test can be modified to evaluate different sample sizes and configurations. Most military and electronic industry specifications require decay time to be measured to the 1% (50 volt) cutoff level (previously designated as 0%). Applications referenced to NFPA (National Fire Protection Association) specifications require the decay time to be measured to the 10% (500 volt) cutoff level.

CALIBRATION CHECK
Prior to a static decay evaluation, a performance system check is made on the Model 406 using the ETS System Test Module (STM). The STM is placed in the Faraday Test Cage in lieu of a test specimen.

It produces a known decay time when plus and minus 5kV is applied. This test checks both the accuracy of the decay time measurement and the balance in decay times between positive and negative charging voltage polarities.

INITIAL CHARGE AND ACCEPTED CHARGE

Material that is static dissipative or conductive will have no measurable static charge on the surface and will be able to conduct the 5kV charging voltage across the surface when applied. A sample that has a measurable initial charge prior to applying the charging voltage indicates that the sample is either insulative or contains both dissipative and insulative characteristics on the surface. The magnitude of the initial charge is listed in the *IC Volts* column of the data sheet. Generally, a material that has both an initial charge and accepts the applied 5kV will not have a measurable decay time if the cutoff selected is below the level of the initial charge. Material with an initial charge, a very long or no charge/decay characteristics can be evaluated by noting the amount of charge conducted across the surface of the test material after applying 5kV for one minute. The more charge accepted after one minute, the more dissipative the material. This value is listed in the *AC Volts* column of the data sheet. No readings would be recorded under *Decay Time*.

POINT-TO-POINT & POINT-TO-GROUND RESISTANCE

Surface resistance measurements between two points or between a point and groundable point are performed using a Dr. Thiedig Milli-TO-2, or an ETS Model 871 Wide Range Resistance Meter and two ETS Model 850 Surface Resistance Probes or a single probe and a clip connection to the groundable point. Standard ESD S4.1 specifies the measurement of resistance between two 5lb probes with 2.5” diameter conductive rubber electrodes for point-to-point resistance, and between one probe and the groundable point for worksurfaces. The placement of the probes on the worksurface is defined in the specification. Measurements at low humidity are specified using a test voltage of 10 volts. At moderate humidity the test voltage is specified at 100 with acceptable materials having a resistance less than 1×10^9 ohms.

TRIBOELECTRIC CHARGE GENERATION

Triboelectric charge generation evaluates the ability of a material to generate a charge when rubbed or separated from another material or from itself. A material that resists tribocharging is referred to as being "antistatic". Figure 1 shows the Triboelectric Series listed in Mil-HNDBK-263 which gives a ranking of the polarity of various materials and their relationship to other materials. According to ESD Advisory ADV 11.2 "Tribocharging", many variables can effect triboelectric charge testing. These variables include the following:

Environmental: R.H., Temperature and Conditioning Time.

Mechanical: Area of Contact, Duration of Contact, Pressure of Contact, Speed of Separation, Speed of Rubbing Motion, Re-abrasion of same area.

Electrical: Extraneous Electrical Fields, Charge Neutralization (Ionization), Charge Measurement Equipment.

Materials: Geometry, Surface Features (roughness), Conductivity, Surface Contamination, Lubricity, Variance between Points on the same Specimen, Work Function and Fermi Level Differences between two materials.

Misc: Data Interpretation

TRIBOELECTRIC SERIES

POSITIVE (+)

Human Hands
Rabbit Fur
Glass (Quartz)
Mica
Human Hair
Nylon
Wool
Fur
Lead
Silk
Aluminum
Paper
Cotton
Steel
Wood
Amber
Sealing Wax
Hard Rubber
Nickel, Copper
Brass, Silver
Gold, Platinum
Sulfur
Acetate Rayon
Polyester
Celluloid
Orlon
Polyurethane
Polyethylene
Polypropylene
PVC
KEL F
Silicon
Teflon

NEGATIVE (-)

Figure 1

Triboelectric charge generation can be evaluated using a number of different techniques. Currently, the most widely used industry test procedure is the Inclined Plane Test. This test evaluates the ability of the test material to charge other materials that are situated on opposite ends of the Triboelectric Series. The charge levels developed on the cylinders give a relative ranking of the antistatic characteristics of the test material. The test is designed to evaluate relatively flat smooth material.

The test procedure consists of rolling clean, neutralized 1" dia. x 1.0" Teflon and Quartz cylinders down a 4" Wide x 12" long specimen of material which is mounted to a plane inclined at an angle of 15°. The cylinders are dropped into a Faraday cup connected to a Nanocoulombmeter and the charge on the cylinders is measured.

TEST RESULTS

The actual data is contained in the enclosed data sheets.

STATIC DECAY

Testing at 12% RH

The samples were charged to ±5kV and the time to dissipate 99% of the charge (1% cutoff) when grounded was measured.

	MIN	**MAX**	**AVERAGE** (Seconds)
A) Merino ESD Laminate	0.01	0.85	0.04

No initial charges were recorded and the full 5kV charge was accepted.

Testing at 50% RH

The samples were charged to ±5kV and the time to dissipate 90% of the charge (10% cutoff) when grounded was measured.

	MIN	**MAX**	**AVERAGE** (Seconds)
A) Merino ESD Laminate	0.01	0.01	0.01

No initial charges were recorded and the full 5kV charge was accepted.

POINT-TO-POINT AND POINT-TO-GROUND RESISTANCE

POINT-TO-POINT RESISTANCE

Testing at 12% RH	MIN	MAX	AVG
A) Merino ESD Laminate	$1.17 \times 10^{8}\ \Omega$	$4.77 \times 10^{8}\ \Omega$	$2.50 \times 10^{8}\ \Omega$
Testing at 50 % RH			
A) Merino ESD Laminate	$1.03 \times 10^{6}\ \Omega$	$1.48 \times 10^{6}\ \Omega$	$1.25 \times 10^{6}\ \Omega$

Testing was performed using a test voltage of 100 volts.

POINT-TO-GROUND RESISTANCE

Testing at 12% RH	MIN	MAX	AVG
A) Merino ESD Laminate	$4.40 \times 10^{7}\ \Omega$	$1.41 \times 10^{8}\ \Omega$	$8.26 \times 10^{7}\ \Omega$
Testing at 50 % RH			
A) Merino ESD Laminate	$8.60 \times 10^{5}\ \Omega$	$3.80 \times 10^{7}\ \Omega$	$1.87 \times 10^{7}\ \Omega$

Testing was performed using a test voltage of 100 volts.

TRIBOELECTRIC CHARGE EVALUATION

When tested using the Teflon cylinders, the absolute value of the charge generated ranged from 0.55 to 0.95 nC with an average of 0.78 nC. The charge per square inch was 0.25 nC.

When tested using quartz cylinders, the charge generated ranged from 0.18 to 0.51 nC with an average of 0.31 nC. The charge per square inch was 0.12 nC.

Note: Please note that all readings obtained on the Teflon and quartz cylinders were negative. The absolute value of the measurements is used when processing the data.

CONCLUSIONS

Most specifications for static safe material are written for packaging material. These specifications are also referenced for many other static safe applications.

STATIC DECAY

Testing at 12% Relative Humidity
According to electronic industry packaging material specifications such as ESD S.541 (formerly EIA-541) and Mil-PRF-81705E which both utilize MIL-STD-3010 (formerly FTM 101C, Method 4046), a material that has been preconditioned at 12% R.H. for a minimum of 48 hours should have a static decay time of less than 2.0 seconds when measured to a 1% (50 volt) cutoff level to be considered acceptable for use in Static Safe applications.

Testing at 50% Relative Humidity
NFPA 99, which references MIL-STD-3010 (formerly FTM 101C), is commonly referenced for hospitals and hazardous locations and is also used as a guideline for packaging, filtering, paper, consumer products, cleanrooms and many other applications. This specification requires conditioning at 50% R.H. Acceptable materials should have a static decay time of less than 0.50 seconds when measured to the 10% (500 volt) cutoff level.

With average decay times of 0.04 and 0.01 seconds at 12% and 50 % RH respectively, the Merino ESD Laminate samples met the static decay requirement of both specifications and should be acceptable for applications referencing either specification.

RESISTANCE

Specification ESD S20.20 references Test Method ESD S4.1 for evaluating ESD worksurfaces. Acceptable materials should have resistance less than 1 x 10^9 ohms.

With an average Point-to-Point resistance of 2.50 x 10^8 and 1.25 x 10^6 ohms at 12% and 50% RH respectively, the samples met the above requirement. With average Point-to-Ground resistance of 8.26 x 10^7 and 1.87 x 10^7 ohms at 12% and 50% RH respectively, the samples also met the above requirement.

TRIBOELECTRIC CHARGE GENERATION

Triboelectric charge generation tests give an indication of the relative antistatic characteristics of the objects being separated. Many factors affect the magnitude of this triboelectric charge such as humidity, material construction, speed and force of separation. During the actual manufacturing process, the charge build-up on a given material can be many times higher than the charge generated in a laboratory environment. Industry advisory method ESD ADV 11.2 do not define acceptance limits but leave it up to the end user to determine if a material can be used for a specific application. In general, the electronics industry references an average of 0.50 nC or less as an acceptable limit. In other cases, end users reference the information as "nC/in^2". In these cases, limits of 0.19 and 0.13 nC are referenced as upper acceptance limits for packaging materials.

With an average measurement of 0.78 nC for Teflon the measurements were above the suggested limit. With an average of 0.31 nC the quartz measurement was within the suggested limits referenced for use in static safe applications. Individual companies, however, may reference other limits that address their specific needs.

NOTE: The data contained in this report has been generated using established industry, DOD, ETS or customer standards. Results and conclusions are based on the specific samples tested on this date under the environmental conditions listed. **Ultimately, it is the responsibility of the end user to determine if a material is acceptable for use in a specific application.**

REVIEWING YOUR DATA SHEETS

HEADER
Lists the purchase order, sample description, test conditions, date of test and the equipment used.

TEST RESULTS
Lists the individual measurements taken on each sample along with the polarity of the test voltage.

DATA ANALYSIS OF INDIVIDUAL SAMPLES
Average, standard deviation, range, minimum & maximum analysis for individual samples.

DATA ANALYSIS OF GROUPS
Average, standard deviation, range, minimum & maximum for each group of specimens giving the customer an overview of the performance of a group. This section is useful in providing information on specification compliance, group uniformity, etc.

AVERAGE
The mean value of all readings. The readings are summed and divided by the total number of data points.

STANDARD DEVIATION
The standard deviation represents the reliability of the data obtained. The higher the standard deviation, the more likely it is that readings far from the average will be obtained in subsequent tests. The standard deviation is calculated by taking the square root of the sum of the squares of the numeric difference between the reading and the average for each sample, divided by the number of readings considered.

nC/SQ.INCH
In testing for triboelectric charge generation, the total charge on the quartz or Teflon cylinder is recorded by the Nanocoulombmeter. Because this charge in generated by the separation of the cylinder from the material, the total charge is dependant on the surface area that comes into contact with the material. Since there is a difference in diameter between the Teflon and quartz cylinders, the surface area per unit area normalizes the results between each cylinder type.

Teflon 1"L x 1.00" dia.	Quartz 1"L X 0.833" dia.
Surface Area = 3.14 sq. inch	Surface Area = 2.62 sq. inch

MINIMUM
The lowest reading obtained in a sample group.

MAXIMUM
The highest reading obtained in a sample group.