MATERIAL EVALUATION REPORT

STATIC DECAY, SURFACE RESISTIVITY AND SURFACE RESISTANCE TESTING OF MAT SAMPLES

NEW PIG CORPORATION

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<u>GENERAL</u>

Electrostatic characterization tests were performed by ETS Testing Laboratories on samples submitted by New Pig Corporation under Purchase Order Number 13835dlm. Four (4) material types were tested for static decay, surface resistivity and surface resistance compliance.

<u>TEST CONDITIONS</u>

Date of Test:	9/17/09
Humidity:	50.5% RH
Temperature:	74°F
Conditioning Time:	48 Hours

<u>TEST APPARATUS</u>

HUMIDITY CONTROL

ETS Series 5000/5500 Controller and 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.

STATIC DECAY

An ETS Model 406 Static Decay Meter is used to perform static decay measurements. An ETS STM-1 System Test Module is used to verify the calibration of the Static Decay Meter.

SURFACE RESISTIVITY/SURFACE RESISTANCE

Surface resistivity and surface resistance measurements of planer material are performed using a Dr. Thiedig Milli-TO-2 Wide Range Resistance Meter in conjunction with an ETS Model 803B Surface/Volume Resistivity Probe. An ETS Model 809B Calibration Check Fixture is used to verify the calibration of the resistance test set-up.

<u>TEST METHODS</u>

The following test methods and specifications were used in the evaluation of the test material:

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 Model STM-1 System Test Module. The STM-1 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*.

SURFACE RESISTIVITY/SURFACE RESISTANCE

Surface resistivity per ASTM-D 257 has generally been the property used to describe the conductive, dissipative or insulative range of static control material. The ETS Series 800 probes conform to the concentric ring design specified. The ratio between the inner and outer electrodes results in a surface resistivity equal to 10X the measured resistance. It should be noted that surface resistivity is expressed in ohms per square, without regard to the size of the square.

Surface resistance per ESD S11.11 is used to evaluate static dissipative material. This resistance is equal to the actual resistance measured with the Model 803B Probe. A test voltage of 10 volts is specified for resistances between 10^4 and 10^6 ohms. A test voltage of 100 volts is required for resistances between 10^6 and 10^{11} ohms. Surface resistance is expressed in ohms. Resistance measurements below or above these values may require different test voltages. Conductive materials (those materials with surface resistances below 10^4 ohms) are measured using either a current source (cs) or voltages equal to or less than 10 volts.

TEST RESULTS

The actual data taken is contained in the enclosed data sheets.

STATIC DECAY

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

GROUP	**MIN**	**MAX**	**AVERAGE** (Seconds)
A (Mat 203)	0.01	0.04	0.02
a (Mat 203 Reverse)	0.01	0.02	0.01
B (Mat 215)	0.01	0.01	0.01
b (Mat 215 Reverse)	Less than 0.01	0.01	0.01
C (Mat 301)	0.01	0.01	0.01
c (Mat 301 Reverse)	0.01	0.01	0.01
D (Mat 414)	Less than 0.01	0.01	0.01
c (Mat 414 Reverse)	Less than 0.01	0.01	0.01

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

SURFACE RESISTIVITY

GROUP	**MIN**	**MAX**	**AVERAGE** (Ohms/Sq.)
A (Mat 203)	9.80×10^{9} Ω/sq.	1.82×10^{10} Ω/sq.	1.43×10^{10} Ω/sq.
a (Mat 203 Reverse)	1.00×10^{10} Ω/sq.	1.35×10^{10} Ω/sq.	1.15×10^{10} Ω/sq.
B (Mat 215)	1.85×10^{9} Ω/sq.	4.50×10^{9} Ω/sq.	2.96×10^{9} Ω/sq.
b (Mat 215 Reverse)	2.34×10^{9} Ω/sq.	4.36×10^{9} Ω/sq.	3.46×10^{9} Ω/sq.
C (Mat 301)	1.18×10^{9} Ω/sq.	1.65×10^{9} Ω/sq.	1.45×10^{9} Ω/sq.
c (Mat 301 Reverse)	9.70×10^{8} Ω/sq.	1.51×10^{9} Ω/sq.	1.29×10^{9} Ω/sq.
D (Mat 414)	2.05×10^{8} Ω/sq.	4.65×10^{8} Ω/sq.	2.82×10^{8} Ω/sq.
d (Mat 414 Reverse)	2.32×10^{8} Ω/sq.	4.42×10^{8} Ω/sq.	3.44×10^{8} Ω/sq.

Testing was performed using a test voltage of 100 volts.

SURFACE RESISTANCE

GROUP	MIN	MAX	AVERAGE (Ohms)
A (Mat 203)	9.80×10^{8} Ω	1.82×10^{9} Ω	1.43×10^{9} Ω
a (Mat 203 Reverse)	1.00×10^{9} Ω	1.35×10^{9} Ω	1.15×10^{9} Ω
B (Mat 215)	1.85×10^{8} Ω	4.50×10^{8} Ω	2.96×10^{8} Ω
b (Mat 215 Reverse)	2.34×10^{8} Ω	4.36×10^{8} Ω	3.46×10^{8} Ω
C (Mat 301)	1.18×10^{8} Ω	1.65×10^{8} Ω	1.45×10^{8} Ω
c (Mat 301 Reverse)	9.70×10^{7} Ω	1.51×10^{8} Ω	1.29×10^{8} Ω
D (Mat 414)	2.05×10^{7} Ω	4.65×10^{7} Ω	2.82×10^{7} Ω
d (Mat 414 Reverse)	2.32×10^{7} Ω	4.42×10^{7} Ω	3.44×10^{7} Ω

Testing was performed using a test voltage of 100 volts.

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

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 all measurements less than 0.04 seconds and average measurements ranging from 0.01 to 0.02 seconds all four samples groups met the static decay requirement of the specification.

RESISTANCE AND RESISTIVITY

Resistance measurements are used in the static control industry to help categorize materials. Although resistance and resistivity measurements alone cannot tell everything about a material's electrostatic performance, it is a good indicator, can help to establish a baseline, indicate differences between additives or additive levels, show differences within a sample group and characterize the effects of relative humidity on a material's performance. Depending on the specification referenced and the composition of the material, either surface resistivity or surface resistance (or both) may be applicable.

NFPA 99, which uses test method ASTM-D-257 and requires conditioning at 50% RH, has an upper acceptance limit of 1 x 10^{11} Ω/sq at 50% R.H. Materials with resistivity measurements below this limit are considered acceptable. According to industry packaging material specifications such as ESD S.541 (formerly EIA-541) and Test Method ESD STM 11.11, Material having a surface resistance measurement of less than 1 x 10^4 ohms is considered conductive, between 1 x 10^4 and 1 x 10^{11} ohms is considered dissipative and readings greater than 1 x 10^{11}ohms would classify the material as insulative.

With average surface resistivity measurement ranging from of 2.82 x 10^8 to 1.43 x 10^{10} ohms/sq., all four sample groups met the surface resistivity requirement of the specification for a dissipative material.

With average surface resistance measurement ranging from of 2.82 x 10^7 to 1.43 x 10^9 ohms, all four groups met the surface resistance requirement of the specification for a dissipative material.

It should be noted that sample group Mat 414 had the lowest surface resistivity and resistance measurements.

Ultimately it is up to the end user to determine if a material is suitable for use in static safe applications. All four samples groups met the decay, surface resistance and surface resistivity requirements of the above specifications at 50% RH and should be acceptable for use in ESD Safe applications referencing these test methods.

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.

MINIMUM
The lowest reading obtained in a sample group.

MAXIMUM
The highest reading obtained in a sample group.