SURFACE & VOLUME RESISTANCE/RESISTIVITY TEST FIXTURE

Model 853

Operating Instructions

10/10

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1.0 INTRODUCTION

EN 1149-1 and 1149-2 are a European Standards that are part of test methods and requirements for electrostatic properties of protective clothing. The method of EN 1149-1 is most appropriate for materials for which the electrostatic dissipative behavior is based on surface conductivity. It determines resistance over short distances and may not be appropriate for evaluating full garments.

The method of EN 1149-2 is most appropriate for complete garments for which the electrostatic dissipative behavior is based on the bulk conductivity of the material.

These specifications specify test methods for materials intended for use in the manufacturing of electrostatic dissipative protective clothing (or gloves) to avoid incendiary discharge. These test methods are not applicable for materials used in the manufacture of protection clothing or gloves against line (mains) voltages.

There are also many applications where the resistance or resistivity properties of static dissipative and insulating type materials are required. Other similar test methods such as ANSI/ASTM D 257 that is a standard test method for the measurement of "D.C. RESISTANCE OR CONDUCTANCE OF INSULATING MATERIALS". That covers direct current measurements for determining the DC surface and volume resistivity of electrical insulating materials. ANSI/ESD STM11.11 and STM11.12 are standards for determining the surface and volume resistance characterization of planer, static dissipative material respectively.

Resistance/resistivity measurements are used for predicting the ability of insulating type materials to dissipate a buildup of electrostatic charge. Materials that are coated, chemically treated or contain an internal antistatic agent have static dissipative characteristics that are a function of surface resistance/resistivity. On the other hand, materials that are loaded with a conductive material, such as carbon, are both surface and volume conductive. In most cases a material that is volume conductive is also surface conductive but there are certain composites or laminates where this rule does not hold true.

During the development of new static dissipating materials or coatings, it is necessary to know the material resistance/resistivity in order to predict the static dissipative characteristics. Likewise, it is also necessary to measure this parameter during the evaluation and qualification of existing materials where the expected resistance/resistivity values are known.

In the static control field a number of military, industry and individual company standards exist that specify the surface and/or volume resistivity as a material specification requirement. Among these standards are Mil Std 883, EIA-541, and numerous company specifications such as those originally issued by Bellcore, Hewlett Packard, IBM, Seagate, etc.

ANSI/ASTM D 257 describes several measurement techniques and measuring electrode types for determining resistivity. The ETS Model 853 Surface Resistance/Resistivity Test Fixture is a circular measuring electrode that is based around the concentric ring electrode design specified in the standard. This electrode configuration, shown in Figure 1.0-1, restricts the measurement path (surface resistivity) to just the area between the two concentric ring electrodes, thus eliminating measurement errors attributed to stray current paths such as those experienced with parallel bar electrodes. The standard Model 853 is designed such that the measured surface resistance is converted to surface resistivity by multiplying the measured resistance by a factor of 20. The unit illustrated in Figure 1-1 is specifically designed to measure the surface resistivity of electrostatic dissipative protective clothing as specified in EN 1149-1 and is also used to measure the volume resistance as specified in EN 1149-2..

Figure 1.0-1:Model 853 Surface Resistance/Resistivity Test fixture

2.0 EQUIPMENT DESCRIPTION

The Model 853 Surface & Volume Resistance/Resistivity Test Fixture is designed in accordance to the test fixture specified in EN 1149-1 and 2. The concentric ring design incorporates a geometrical configuration that provides an x20 multiplication factor to convert the surface resistance measurement to surface resistivity. The design of the Model 853 Probe electrode configuration is derived from the applicable formulas set forth in EN 1149-1. For the concentric ring design the surface resistivity, ρ_s, is a function of the ratio between the inner and outer ring diameters as shown in the following formula:

$$\rho_s = \frac{\pi(D_1 + D_2)}{(D_2 - D_1)} R_m \text{ Ohms/sq.}$$

D_1 = Outside Diameter of inner ring
D_2 = Inner Diameter of outer ring
R_m = Measured resistance in Ohms

By properly choosing D_1 and D_2, the factor $(D_1 + D_2)/(D_2 - D_1)$ can be made to equal any reasonable number. In the case of the Model 853, $\pi(D_1 + D_2)/ (D_2 - D_1)$ equals 20, resulting in a surface resistivity measurement of

$$\rho_s = 20R_m \text{ Ohms/square}$$

The numeric value of ρ_s is actually in Ohms. The designation Ohms/square clarifies the number as a surface resistivity measurement.

The Model 853 can also be configured to measure volume resistance by connecting the Source voltage to the ground plane that is used as a guard ring when measuring surface resistance. Volume resistivity is a function of the area of the inner electrode and the thickness of the test specimen. Volume resistivity, ρ_v, must always be calculated because the thickness of the test specimen is one of the measurement variables. The ANSI/ASTM D 257 formula for ρ_v is

$$\rho_v = \frac{A}{t} R_m \text{ Ohms-cm}$$

A = Area of measuring electrode in cm^2 ($20cm^2$)
t = Thickness of test specimen in cm
R_m = Measured resistance in Ohms

The Model 853 electrodes are made from compliant material of nickel impregnated silicon rubber with a nominal hardness of 60 durometer that provides good probe/surface contact. For most materials, the need to apply additional pressure is not necessary. The resistance of the electrode contact material is less than 10 Ohms enabling the probe to also measure very low resistance material.

The Model 853 Surface & Volume Resistance/Resistivity Test Fixture is compatible with any resistance meter having standard 4mm banana jacks and is capable of measuring over the desired measurement range of the material under test.

2.1 Model 853 Components

The following components shown in Figure 2.0-1 are supplied with the Model 853 Surface and Volume Resistance/Resistivity Test Fixture;

1. Test Fixture, Inner and Outer Electrodes
2. Ground Plane
3. Acrylic Insulated Surface
4. 48” (1.22m) Shielded SENSE cable
5. 60” (1.5m) SOURCE cable (Red)
6. 60” (1.5m) GROUND cable (Green)
7. BNC to banana jack adapter for resistance meters with banana plug leads
8. Operating Manual

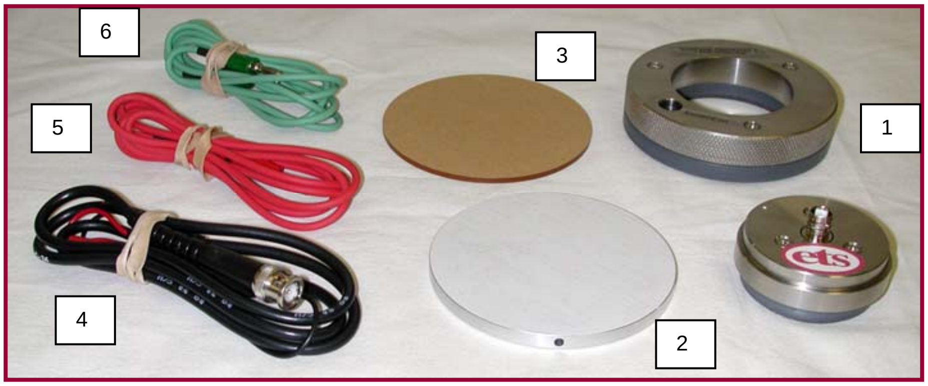

Figure 2.0-1: Model 853 Components

3.0 OPERATION

3.1 Instrumentation

The Model 853 Surface & Volume Resistance/Resistivity Test Fixture can be used with any Ohmmeter or resistance measuring apparatus that is capable of measuring within the desired resistance range as shown in Figure 3.0-1. The Test Fixture has a shielded SENSE cable and 2 standard banana plug cables for connection to the measuring instrument. The inner electrode (SENSE) is connected using a shielded cable with BNC termination on the Probe side and Standard Banana plugs on the meter end. The outer electrode (SOURCE) is connected to the meter via a standard banana plug.

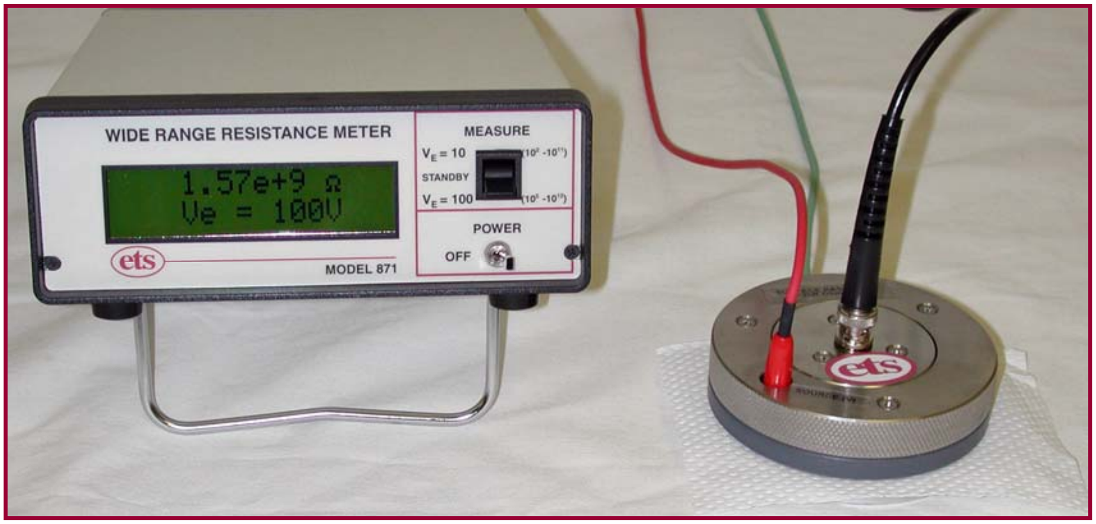

Figure 3.0-1a: Measuring a sample using ETS Model 871

When using the ETS Model 863/487 Resistance Meter or any other meter having dedicated banana plug leads a **BNC to Banana converter** is required to connect the SENSE lead as shown in Figure 3.0-1b.

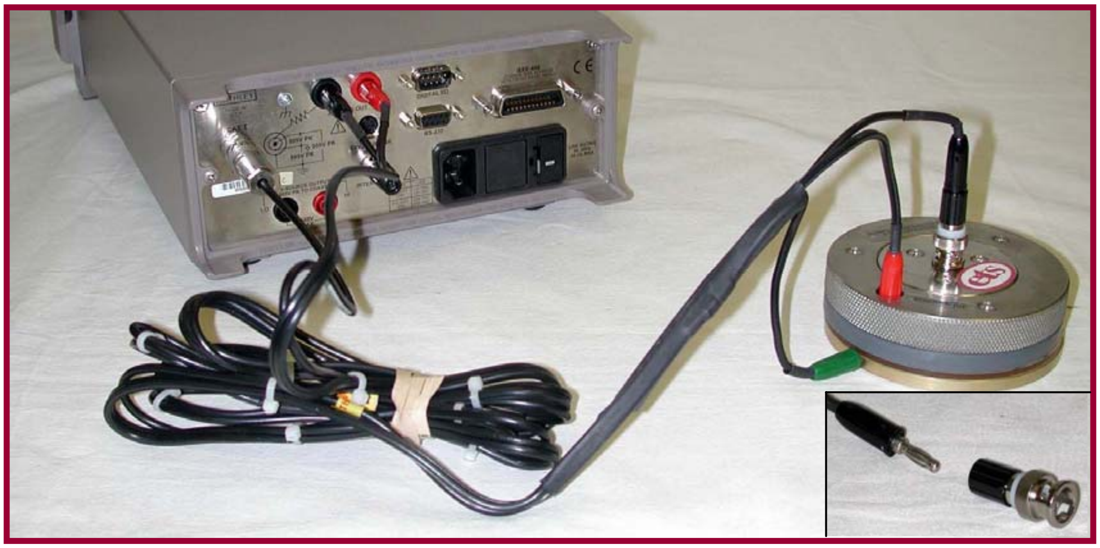

Figure 3.0-1b: Measuring a sample using ETS Model 863/487

NOTE

Depending on the meter being used the input connectors may be color coded, usually red and black. The shielded cable supplied with the Model 853 has a Red banana plug that connects to the SENSE (center) electrode and a black banana plug for the shield (ground). Some meters have a Red banana jack for the SOURCE (Test Voltage), a Black banana jack for the SENSE and a Green banana jack for Ground such as the ETS Model 871 and 873. Other meters may have either a green, black or all-metal banana jack or connection for ground.

Whatever meter is used the SOURCE (Voltage) is applied to the outer electrode and the SENSE (Red banana plug on shielded cable is connected to the other meter input irrespective of the cable and/or connector color.

3.2 Equipment Setup

3.2.1 Surface Resistivity

Figure 3.0-2 shows a typical Model 853 Test Fixture hookup to a resistance meter for measuring surface resistance/resistivity. The SENSE cable is connected to the Inner electrode (BNC connector) and the SOURCE (voltage) cable is connected to the Outer Electrode. The SENSE cable is connected to the SENSE input of the meter and the shield connected the ground (Green, black or bare) terminal on the meter or directly to the power outlet 3rd wire ground. (This ground connection is not necessary for resistances less than 10^8 Ohms).

If a meter having only two output connections is used, connect the HI side (usually red) to the Outer electrode and the LO side (usually black), to the Inner electrode.

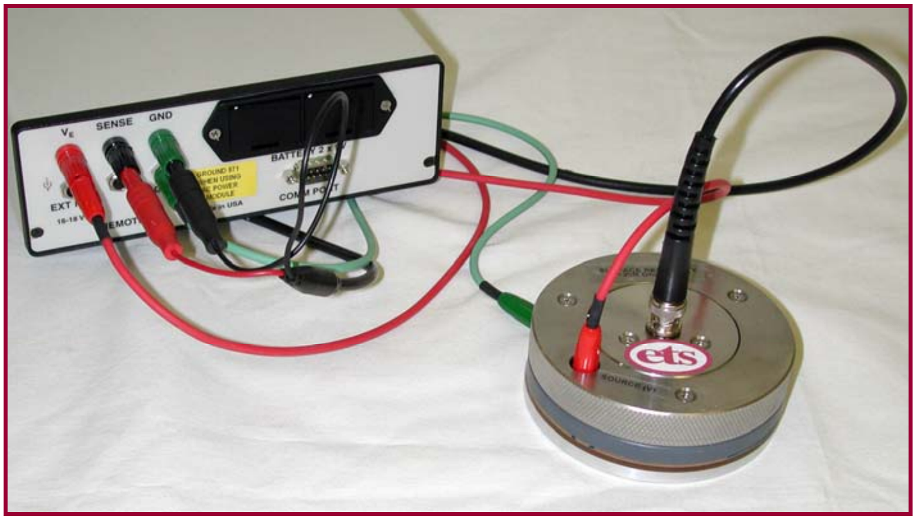

Figure 3.0-2:Model 853 Probe/Resistance Meter Hook-up for Surface Resistivity Measurement (EN 1149)

3.2.2 Volume Resistivity

The Model 853 Probe can be hooked up to a resistance meter for measuring volume resistance as shown in Figure 3.0-3. The Sense cable remains connected to the Inner electrode (Black jack) but the voltage cable is now connected to the volume resistance measurement plate (The same plate as is used for the guard for surface resistivity. The Outer ring electrode is then connected to ground (D257) when measuring the volume resistivity of insulating material (>10^{12} Ohms). For static dissipative material per ESDS STM11.12, the Outer electrode is **<u>not</u>** connected for resistance measurements less than 10^5 Ohms.

Figure 3.0-3: Probe/Resistance Meter Hook-up for Volume Resistance Measurement

3.3 Measurement of Surface Resistivity, ρ_s

3.3.1 Material Considerations

The standard Model 853 Test Fixture is designed specifically to accurately measure the surface resistance/resistivity of dissipative protective clothing or virtually any other smooth surface. If used to measure rigid materials that may have a slight bow or uneven surface additional weight may have to be added or additional force applied to the probe to ensure total contact. Microscopically, hard surfaces may not be perfectly smooth and/or flat as illustrated in Figure 3.0-4.

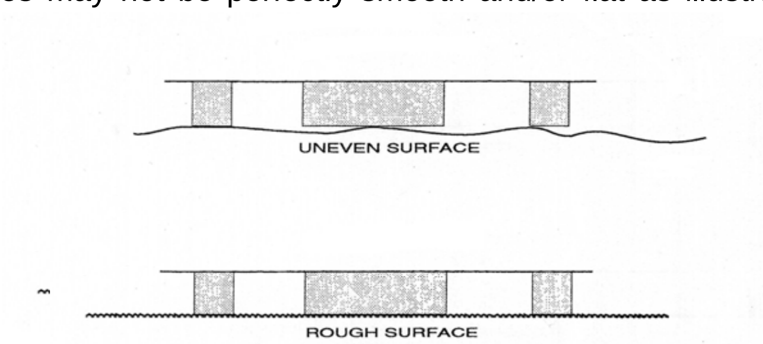

Figure 3.0-4 Microscopic Electrode/Rigid Surface Contact

In most cases the application of additional pressure will cause the measured resistance reading to decrease. This is a result of both lower contact resistance and greater electrode/surface contact area (greater number of parallel resistance paths).

Another area that must be considered when attempting to make a surface resistance measurement is the composition of the material being evaluated.

3.3.2 Measuring Considerations

3.3.2.1 Time of Electrification

In the previous section the effect of contact pressure, which actually alters the contact area, on the measurement accuracy was discussed. Another very important consideration that many times is ignored is what is referred to as the "time of electrification". In simple terms the time of electrification is the time for current to flow between the measuring electrodes. All materials have, in basic terms, some capacitance. When measuring low resistances this capacitance is negligible in relation to the resistance of the material. Therefore, the current flow essentially becomes restricted by the resistance of the material only.

For total charging, five times constants (5τ) are the accepted norm. Therefore, if a measurement system/material has a total capacitance of 1 picofarad and a resistance of 1×10^{12} Ohms,

$$\tau = RC = (1 \times 10^{12}) \times (1 \times 10^{-12}) = 1 \text{ second}$$

The total charging time is t = 5 seconds. This is the time of electrification. It is seen that if the capacitance is only a few picofarads the time of electrification can stretch out to many seconds. Resistances that are measured before the full time of electrification has occurred will be less than the actual resistance of the surface. This difference can be several orders of magnitude. ASTM D 257 recommends a time of electrification of 60 seconds, however lower resistance measurements may be made using a shorter time and very high resistance may require a longer time. Usually for small sample specimens with resistances less than 10^{10} ohms, an electrification time of 10 to 15 seconds is sufficient or the point at which the resistance measurement stabilizes. On the other hand, with large surfaces, such as full garments the capacitance is relatively large and 60 seconds may not be long enough. Here, the user may either wait for the complete electrification and obtain a true resistance measurement or specify the measurement at the 60 second electrification time point for a relative resistance measurement. **EN1149 specifies an electrification time of 15 seconds.**

In any case, the time of electrification is a critical parameter in the measurement of resistance/resistivity and must be taken into account if meaningful results are to be obtained. ESDA STM11.11 requires the determination of the actual electrification time as part of the measurement procedure.

3.3.2.2 Test Voltage

Certain materials are voltage dependent, that is, the resistance measured at one test voltage will not be the same as that measured with a different voltage. Generally, test voltages of 100, 500 and 1000

Volts are used for very high resistances (10^9 Ohms and above) while test voltages of 10, 20, 50 and 100 Volts are used for lower resistances in the range of 10^3 to 10^{12} Ohms. Some instruments use a single voltage to cover a wide resistance range of 10^3 to 10^{12} Ohms. **EN 1149 specifies a test voltage of 100 Volts for material having surface resistances above $1x10^5$ and an appropriate lower voltage such as 10 Volts for resistances below $1x10^5$ Ohms.**

Another consideration is the contact resistance between the Probe electrodes and the material surface. For certain materials, especially those in the lower resistance range ($<10^6$ Ohms), the contact resistance can be a factor. At low ranges, a test voltage of 1.5 Volts may be used. This low voltage may not be sufficient to breakdown the contact resistance or the dielectric between conductive particles. Hence, a significant difference in measured resistance may be obtained using 1.5 and 10 Volts and even between 10 and 100 Volts.

When establishing resistance/resistivity requirements or when comparing resistance/resistivity measurements, the user must specify the test voltage. Failure to do so could result in large measurement differences between different test set-ups.

3.3.2.3 Measurement Procedure

The above information is provided to enable the user to make meaningful and accurate surface resistance/resistivity measurements with the Model 853 Surface Resistance/Resistivity Test Fixture.

The following is a recommended procedure to be followed when measuring surface resistance/resistivity:

1. Determine the type of material being measured. Use the precautions described in the previous sections.

2. Make certain the contact electrodes are clean. The electrodes may be cleaned with Isopropyl alcohol.

3. Place the Probe firmly on the surface to be measured. If the material to be tested is soft or very flat, additional pressure should not be required.

4. Select the appropriate test voltage and resistance range.

5. Observe the meter reading for 15 seconds. If it is unstable or the test material is appears to be uneven, apply pressure to the Probe. If the meter reading decreases, continue to apply additional pressure until the reading stabilizes.

6. If the meter reading remains stabilized for several

seconds, record the reading.

3.4 Measurement of Volume Resistivity, ρ_V

The same parameters, electrode contact pressure, time of electrification, excitation voltage and material composition must also be taken into consideration when measuring the volume resistivity, ρ_V, of materials.

The volume resistivity of a material is defined as the resistance through a one cubic centimeter of material. The user is cautioned that a relatively low resistance measured through a very thin film may actually describe a material with a very high volume resistivity.

To measure the volume resistance of a material the same testing procedure described in Section 3.3.2.3 should be followed. To obtain the volume resistivity, the thickness of the test material must be measured using a metric micrometer or converting the English measurement to metric (1 mil = 2.54×10^{-3} cm). The volume resistivity is then

$$\rho_V = \frac{A}{t} R_m \text{ Ohms-cm}$$

Where $A = 20cm^2$

Follow the procedure described in ESD STM11.12 for measuring the volume resistance of static dissipative material.

3.5 Other Applications

The Model 853 nickel impregnated electrodes have a very low contact resistance. It is capable of measuring resistances below 10 Ohms. The same measurement procedures and precautions as mentioned above should be observed.

4.0 MAINTENANCE

The Model 853 Surface & Volume Resistance/Resistivity Test Fixture is a precision instrument and it should be handled in the appropriate manner. The alignment of the Inner and Outer electrodes is critical to ensure total surface contact. The silicon rubber contact material is impregnated with nickel to obtain low contact resistance. The user must ensure that the contact area is clean and free of contaminants prior to making a measurement. The probe should not be exposed to atmospheres or surfaces that may corrode the conductive particles. If exposure is necessary, the contacts should be cleaned with Isopropyl alcohol immediately after use.

If the contact electrodes are damaged or the probe knocked out of alignment, the unit must be returned to ETS for repair. The Model 853 does not contain any user replaceable parts.

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5.0 WARRANTY

Electro-Tech Systems, Inc. warrants its equipment, accessories and parts of its manufacture to be and remain free from defects in material and workmanship for a period of one (1) year from date of invoice. It will, at it's discretion, either replace or repair without charge, F.O.B. Glenside, similar equipment or a similar part to replace any equipment or part of its manufacture which, within the above stated time, is proved to have been defective at the time it was sold. All equipment claimed defective must be returned properly identified to the Seller (or presented to one of its agents for inspection). This warranty only applies to equipment operated in accordance with Seller's operating instructions.

Seller's warranty with respect to those parts of the equipment that are purchased from other manufacturers shall be subject only to that manufacturer's warranty.

The Seller's liability hereunder is expressly limited to repairing or replacing any parts of the equipment manufactured by the manufacturer and found to have been defective. The Seller shall not be liable for damage resulting or claimed to result from any cause whatsoever.

This warranty becomes null and void should the equipment, or any part thereof, be abused or modified by the customer of if used in any application other than that for which it was intended. This warranty to replace or repair is the only warranty, either expressed or implied or provided by law and is in lieu of all other warranties. The Seller denies any other promise, guarantee or warranty with respect to the equipment or accessories. In particular, as to its or their suitability for the purposes of the buyer or its or their performance, either quantitatively or qualitatively or as to the products that it may produce and the buyer is expected to expressly waive rights to any warranty other than that stated herein.

ETS must be notified before any equipment is returned for repair. ETS will issue an RMA (Return Material Authorization) number for return of equipment.

Equipment should be shipped prepaid and insured in the original packaging. If the original packaging is not available, the equipment must be packed in a sufficiently large box (or boxes if applicable) of double wall construction with substantial packing around all sides. The RMA number, description of the problem along with the contact name and telephone number must be included in formal paperwork and enclosed with the instrument. Round trip freight and related charges are the owner's responsibility.