

Evaluation Procedure for Electrical Resistance of Electronically Integrated Textiles

Foreword

This evaluation procedure was initially developed as a tool for iterative design and development purposes, using a 2-point probe system. With a 4-point system, it is also suitable for quality control applications. The procedure may be used for resistance measurement of any e-textile material or product. As e-textile technology evolves, more specialized methods, or options within this method, may be developed.

1. Purpose and Scope

1.1 This evaluation procedure determines the electrical resistance of e-textiles. E-textile fabrics or end products with incorporated conductive paths/traces may be evaluated. This method is not for evaluation of yarns or fibers.

1.2 Electrical resistance may be measured as received, or after treatment such as stretch or laundering, etc. The change in resistance due to treatment may also be calculated. For additional guidance in measurement before and after various exposures, refer to AATCC TM210.

2. Principle

2.1 Electrical resistance of specimens is measured using a digital multimeter and surface probes. Option 1 uses a 4-point system. Option 2 uses a 2-point system. Change in resistance is calculated from measurements before and after treatment, if desired.

3. Referenced Documents

3.1 AATCC TM76, Test Method for Electrical Surface Resistivity of Fabrics (see 15.1).

3.2 AATCC TM210, Test Method for Electrical Resistance Before and After Various Exposure Conditions (see 15.1).

3.3 ASTM D1776, Standard Practice for Conditioning and Testing Textiles.

3.4 ASTM E1402, Standard Guide for Sampling Design.

4. Terminology

4.1 **conductive element, n.**—in *e-textiles*, a fiber, fabric, ink, film or other material that is permanently integrated into a textile that will support the flow of electrons, generally with electrical resistance of less than 500 k Ω .

4.2 **electrical resistance, n.**—a conductive element's response to limit the flow of electrical current in response to an applied voltage or electric field.

4.3 **electronically-integrated textile (e-textile), n.**—a fabric or textile product with permanently-integrated electrical or electronic circuits, or parts of electrical or electronic circuits.

5. Safety Precautions

5.1 These safety precautions are for information purposes only. The precautions are ancillary to the testing procedures and are not intended to be all inclusive.

5.2 It is the user's responsibility to reference applicable safety data sheets, use safe and proper techniques, and wear appropriate personal protective equipment in handling materials in this test method.

5.3 Users MUST consult manufacturers for specific details such as equipment operating instructions and other recommendations. Consult and follow all applicable health and safety regulations (e.g., OSHA standards and rules).

6. Limitations

6.1 Each conductive path to be measured must be accessible, at least at the 2 measurement points. Connectors may be used to provide accessibility. The measured specimen should mimic the intended design of the end product, if known.

6.2 Refer to multimeter or ohmmeter user's manual for applicable range. Test

low-resistance samples ($< 1 \Omega$) with a 4-point system to eliminate lead resistance.

6.3 Refer to AATCC TM76 for samples having a resistance higher than $10^5 \Omega$.

7. Apparatus and Materials (see 15.2)

7.1 Conditioning facilities and racks with pull-out, perforated shelves for laying specimens flat (see 15.2).

7.2 Flat workbench.

7.3 Indelible ink marking pen (see 15.1) or needle and sewing thread, for making benchmarks.

7.4 Multimeter or ohmmeter.

7.4.1 For Option 1 (4-point measurement), digital multimeter or ohmmeter, stable current, 6.5-digit resolution.

7.4.2 For Option 2 (2-point measurement), digital multimeter, also known as DMM or volt-ohm-meter, VOM. Resolution to 0.1 Ω and 0.9% accuracy.

7.5 Probes, suitable for test material (see 18.3 and Fig. 1).

7.5.1 For magnetic probes, metal plate, ferromagnetic, at least as large as specimen.

7.6 Tape or rule marked in millimeters.

8. Verification

8.1 Verify accuracy of the multimeter or ohmmeter according to manufacturer's instructions. Readings may be verified by measuring the resistance of one or more resistors in the range of specimen resistance.

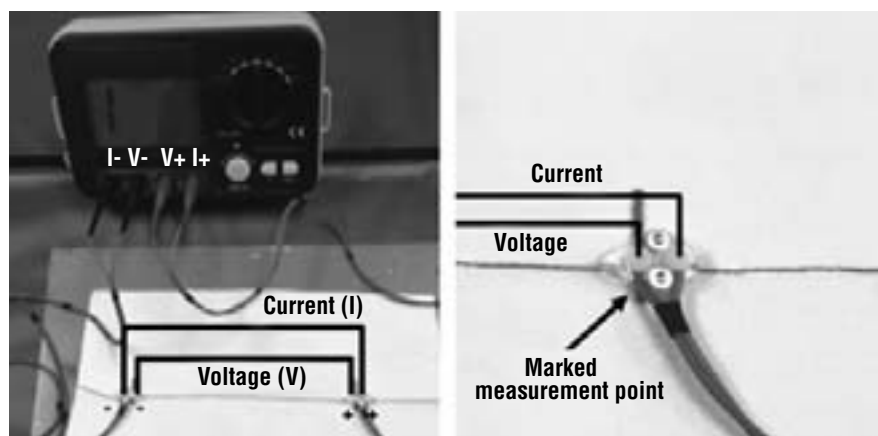


Fig. 1—Ohmmeter and probes for 4-point resistance measurements.

9. Sampling

9.1 Test results are valid only when the samples are statistically representative (see ASTM E1402).

9.2 Sampling must be random. Every unit of product must have a mathematically equal chance of becoming a sample; and every portion of each sample must be equally likely to become a test specimen.

9.3 All specimens must be alike within the variations due to pure chance. There must be no differences within samples assignable to known causes.

10. Specimens

10.1 Each conductive path (or section of a path) is considered a specimen and should mimic the intended design of the end product. Measure at least 3 specimens.

10.1.1 Select specimens that can be arranged to lie flat on the measurement surface with no tension and no risk of a short circuit.

10.1.2 For convenience, straight specimens, 150-300 mm in length, are recommended for development testing.

10.1.3 Specimens from end products will depend upon product design. Complete conductive pathway should be tested.

10.2 Select identical specimens from at least 3 swatches or end products.

10.2.1 Size and shape of swatches or end products is not critical to this evaluation procedure.

10.2.2 If measuring resistance after treatment (stretch, laundering, etc.), refer to the appropriate treatment standard or AATCC TM210 for swatch dimensions.

10.3 Handle specimens with care to avoid contamination, in particular, salts or moisture from human hands, which may affect resistance measurements.

11. Conditioning

11.1 Prior to marking, condition test specimens as directed in ASTM D1776. (Use conditions indicated in Table 1 for Textiles, general. Estimate conditioning time as indicated in Table 2 for the appropriate fiber content.) Lay each swatch or product, separately, on a screen or perforated shelf of a conditioning/drying rack.

12. Preparation

12.1 Mark the ends of each specimen. If sewing thread is used, ensure that needle holes do not interrupt the circuit.

12.1.1 If the conductive path to be measured connects to an electronic system, the mark should be made at the point where the path in the textile connects to the electronic system.

12.2 If fraying of swatches is expected

in treatment, edges may be pinked or serged.

13. Procedure

13.1 For magnetic probes, place the metal plate on a flat work surface.

13.2 Arrange the first specimen on flat, non-conductive surface. For magnetic probes, place specimen directly over the metal plate. Smooth the specimen to eliminate as many folds and wrinkles as possible, but do not stretch.

13.3 Set multimeter to resistance measurement mode. Connect probes to the meter. Use a 4-point system to eliminate lead resistance for all measurements of less than 1 Ω . A 4-point system may also be used for resistance above 1 Ω , but is not required as lead resistance will have less impact on the meter reading. Note the probes or connection system in the report. Do not compare measurements taken using different probes or connection systems.

13.4 Option 1: 4-point measurement.

13.4.1 Place the positive and negative probes of the meter with voltage leads at the marked points. Current leads should be along the same conductive path, outside the voltage leads, but as close to the marked points as possible (see Fig. 1). Ensure consistent pressure throughout the test; weighted or magnetic probes may be used for this purpose.

13.5 Option 2: 2-point measurement.

13.5.1 Place the positive and negative probes of the meter at the marked points. Ensure consistent pressure throughout the test; weighted or magnetic probes may be used for this purpose.

13.6 Record the resistance as soon as the reading stabilizes for a period of 3 s. Take 1 resistance measurement per specimen.

13.7 Measure and record distance between marked points, to the nearest mm.

13.8 Repeat resistance and distance measurements for the remaining specimens.

13.8.1 If only a single specimen is available, measure the resistance of the specimen 3 times. Note this modification in the test report.

14. Evaluation after Exposure (optional)

14.1 Subject specimens to exposures as directed in an applicable standard or AATCC TM210. Record exposure details as directed.

14.2 Recondition specimens (Section 11.1) before final measurement.

14.3 Measure and record electrical resistances after treatment. Use the same marked points and connection system as for the initial resistance measurement.

14.4 Measure and record distance between marked points to the nearest mm.

15. Calculation

15.1 Calculate the mean resistance for all measured specimens. This is R .

15.1.1 If testing was performed before treatment, calculate the mean of initial resistance measurements for all specimens. This is R_i .

15.1.2 If testing was performed after treatment, calculate the mean of final resistance measurements for all specimens. This is R_f .

15.1.3 If only a single specimen was used, calculate the mean of 3 resistance measurements for the specimen.

15.2 Calculate the mean distance between marked points for all specimens, to the nearest mm. This is d .

15.2.1 If testing was performed before treatment, calculate the mean initial distance for all specimens. This is d_i .

15.2.2 If testing was performed after treatment, calculate the mean final distance for all specimens. This is d_f .

15.3 If applicable, calculate % resistance change after treatment using Equation 1.

$$RC = (R_f - R_i) / R_i \times 100\% \quad (\text{Eq. 1})$$

where:

RC = % resistance change after treatment,

R_f = Mean final resistance, after treatment (Ω),

R_i = Mean initial resistance (Ω).

16. Report

16.1 Describe or identify the tested sample.

16.2 Report that the sample was tested using AATCC EP13-2020.

16.3 Report the testing conditions:

16.3.1 Option used (Option 1: 4-point measurement or Option 2: 2-point measurement)

16.3.2 Treatment description and number of cycles, if applicable.

16.3.3 Number of specimens tested.

16.3.4 Description of specimen (conductive path length, width, shape, material, etc.)

16.3.5 Multimeter or ohmmeter resolution and accuracy.

16.3.6 Probe type and connection system.

16.3.7 Distance between marked points for individual specimens.

16.3.8 Mean distance, d , between marked points, to the nearest mm. (Initial distance, d_i , and final distance, d_f , if applicable.)

16.4 Report the test results:

16.4.1 Resistance between marked points for individual specimens.

16.4.2 Mean resistance, R , between marked points. (Initial resistance, R_i , and final resistance, R_f , if applicable.)

16.4.3 Resistance change after treatment, if applicable.