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Subject Linear Electrical Resistance, Conductive Yarn – Four-Wire Method	
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Originating Task Group: Conductive Yarns for E-Textiles Test Methods Task Group	

IPC-TM-650
TEST METHODS MANUAL

1 SCOPE

This test method is used to evaluate the linear resistance of the conductive yarn (RL, in Ω/m) using a four-wire method.

2 APPLICABLE DOCUMENTS

2.1 International Organization for Standardization (ISO)[1]

ISO 139 Textiles Standard atmospheres for conditioning and testing

3 SPECIMENS

3.1 All test specimens **shall** be conditioned for ≥ 24 hours according to ISO 139.

3.2 Each specimen **shall** be ≥ 50 cm [19.68 in].

3.3 The number of specimens **shall** be at least five.

3.4 The specimens **shall** be collected in a manner that will not affect the physical characteristics of the yarn and by using appropriate cutting tool (scissors, wire cutters, etc.).

3.5 A control specimen **shall** be retained for visual inspection comparison.

4 APPARATUS

4.1 Electrical current source for delivering a stable DC current in the range necessary for the measurement.

4.2 Voltmeter capable of measuring voltages in the range necessary for the measurement.

Note: A four-terminal resistance measurement device that includes a constant current source, a voltmeter and a calculation function that calculates the resistance value from them is recommended.

4.3 Clamping mechanism able to clamp yarns with nonconductive contact surface.

4.4 Calibrated ruler for measuring the distance between the voltage electrodes (edge to edge), with the resolution of at least three significant digits in relation to the sample length.

The ruler should be integrated into the clamping mechanism.

1 www.iso.org

5 PROCEDURE

All testing **shall** be performed at standard lab conditions as specified in ISO 139.

5.1 Place the specimen on an insulating surface that has a surface resistivity of >109 Ω. Alternatively, the specimen can be suspended in air.

5.2 Arrange the electrodes as shown in Figure 1.

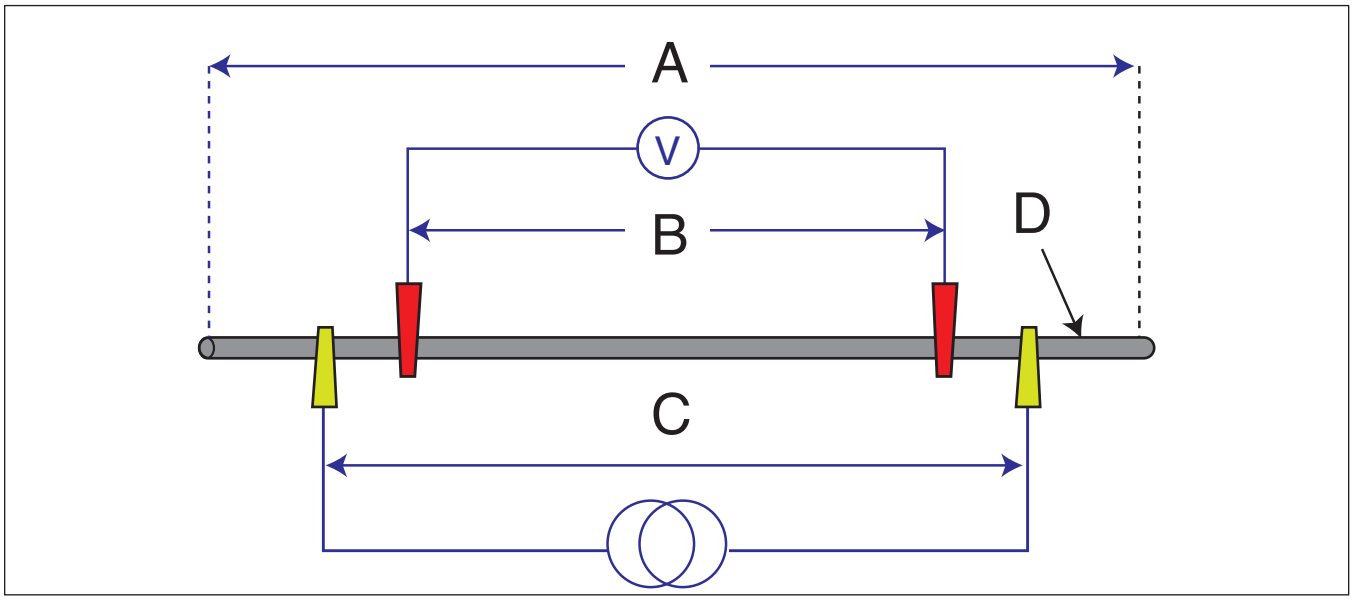

Figure 1 Schematic Test Set-Up for a Four-Electrode / Four-Wire Measurement

A – Specimen length
B – Length between voltage terminals
C – Length between current terminals
D – Conductive yarn

5.3 Any insulating cover or coating **shall** be removed from the conductive yarn points that will be contacted by the electrodes.

5.4 The conductive yarn points **shall** be cleaned to remove materials (e.g., oils, varnish) that can disturb the electrical contact between the electrodes and yarn contact points.

5.5 Tension the specimen to flatten and straighten it for accurately determining the distance. Specimen may be straightened by applying a weight to one extremity of the specimen. A pretensioning of 0.5 cN/tex is recommended, but other values can be used as specified and/or in function of the tensile properties of the yarn.

5.6 Clamp the specimen into the test setup using the recommended tensioning. If mechanical clamping does not yield the necessary measurement stability, contacting needs to be improved using a crimp connector (commercially available crimp connectors for electronic components are suitable).

Note: Good contacting is important to reduce the contact resistance between conductive yarn and the measurement electrode, which influences the effectively measured resistance of the circuit and therefore falsifies the test result. Most important is the stability of the contact resistance.

5.7 Attach the current and voltage terminals to the sample.

5.8 Measure the distance between the current terminals and the distance between the voltage terminals.

5.9 Apply a suitable current (I) and note the value. Avoid resistance heating of the yarn resulting from applying too high of a current.

Note: In many four-terminal ohmmeters, this control is automatic.

5.10 Measure the voltage (V) five times at fixed intervals of time within one minute.

If the values are stable (within two significant digits), note the final value. If the values are not stable, discard the measurement and then recontact and remeasure. If it is not possible to get a stable measurement after three remeasurements, discard the specimen.

5.11 Reclamp and repeat the measurement two times, and for five specimens.

If specified, change the position of the voltage terminal while the current terminal remains fixed to measure resistance at different locations.

5.12 Perform the same measurements for the other four specimens. If any specimen is discarded, additional specimen(s) **shall** be measured such that the minimum number of successful specimens tested is five.

5.13 Evaluation

5.13.1 The linear resistance value RL is obtained by dividing the resistance value by the distance between the voltage terminals in the four-terminal method.

5.13.2 Calculate mean value of RL and standard deviation for the sample, to three significant digits.

6 TEST REPORT

The test report **shall** contain the following items:

- Date and time of test
- Measuring date
- Testing location and name of tester
- Test Method number
- Environmental test conditions (if different from ISO 139)
- Description of test specimens
- Description/Specifications of testing equipment
- Sample ID
- Measurer ID
- In the case of a long yarn sample (e.g., bobbin), the sampling point (the winding starts or winding end of the long yarn)
- Distance between current terminals
- Distance between voltage terminals
- Resistance value
- Line resistance value (resistance value/distance between voltage terminals)
- Test results, including average values and standard deviations
- Visual inspection before and after exposure
- Any deviation from the procedure as specified

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