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Standard Test Methods for Evaluating Connectability Characteristics of Electrical Conductor Materials[1]

This standard is issued under the fixed designation B896; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods define procedures for the relative characterization of conductor material connectability on the basis of measurements of parameters important to the design and performance of electrical contacts and connections to and with such conductors for both power and signal applications.

1.2 The parameters measured are contact resistance as a function of contact force, fretting sensitivity, and compressive relaxation.

1.3 Provision is made for measurement of the connectability parameters at elevated temperature, or corrosive ambient, or both, as may be required for evaluation for particular applications.

1.4 These test methods, using standardized specimen geometry and procedures, are applicable to conductor materials as employed in an electrical system and may be adapted for evaluation of connectability of materials in the form of actual connection system components.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to become familiar with all hazards including those identified in the appropriate Safety Data Sheet (SDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B539 Test Methods for Measuring Resistance of Electrical Connections (Static Contacts)

B542 Terminology Relating to Electrical Contacts and Their Use

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method are in accordance with Terminology B542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *connectability, n*—a combination of properties determining the ability of a material to establish and maintain stable low resistance electrical contact under the influence of deteriorating environmental and operational factors.

3.2.2 *fretting, n*—accelerated surface damage occurring at the interface of contacting materials subjected to small oscillatory displacements.

4. Summary of Test Method

4.1 *Contact Resistance*—Contact resistance is measured as force is increased between conductors in a crossed-rod contact pair of the material(s) being tested. Held at the maximum specified force, test contacts may be exposed to temperature changes or corrosive environments such as high humidity to observe the effects of such conditions on electrical contact resistance.

4.2 *Fretting Sensitivity*—Contact resistance of a crossed-rod pair is measured at constant normal force while a microscopic oscillitory tangential motion is applied at the contact interface. The number of applied motion cycles required to induce contact resistance instability is determined. The test may be performed at elevated temperature or in corrosive environment.

[1] These test methods are under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and are the direct responsibility of Subcommittee B02.11 on Electrical Contact Test Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

4.3 *Compressive Relaxation*—Change of applied contact force with time, at fixed engagement displacement of crossed-wire specimens, is measured. The test may be performed at elevated temperature.

5. Significance and Use

5.1 These test methods develop comparative information useful for the design of stationary contacts for wire, cable, and other conductors.

5.2 These test methods produce results, which are free of the influence of arbitrary connection systems.

5.3 The influence of conductor surface pretreatments and platings can be evaluated by these test methods.

5.4 The influence of environmental factors, such as high temperature and corrosive environment can be evaluated by these test methods.

5.5 The results obtained by these test methods provide guidance on connection system design parameters, such as contact force and gas tightness requirements.

6. Test Methods

6.1 These test methods provide for standardization of specimen geometry, contact loads, and other factors, which may influence the results. Use of nonstandard specimens or procedures may influence the validity of relative connectability comparisons based on the test results.

CROSSED WIRE CONTACT RESISTANCE—FIXED LOAD

6.2 The standard specimen shall be 2 mm (#12 AWG) diameter wire, at least 25 mm long, and straight to within 1 %. Specimens of nonstandard diameter may be used. Resulting performance data only is considered valid for comparison with results on same-size specimens, however.

6.3 The apparatus consists of a fixture capable of performing as follows:

6.3.1 Specimens are oriented perpendicular to one another. Contact between the specimens occurs approximately at the center of each specimen (lengthwise).

6.3.2 Specimens are supported by flat or vee-groove, or equivalent holders, so as to prevent bending due to applied contact load. Specimen support fixture shall support the specimen for a length of 4D ± 0.5D, where D = specimen diameter and shall be centered ±0.5D with respect to the point at which the crossed specimens make contact. Beyond the load support region (at center of the specimens), the specimens shall be unsupported.

6.3.3 Electrical connections to the ends of the specimens shall be made by flexible leads to fixed terminals mounted on the fixture base.

6.3.4 The specimens are brought into contact at a rate of 1 mm/min or less until contact is made. After physical contact is established, the contact force is increased at a rate of 1 kg/min with a maximum allowable lateral motion of 0.025 mm. Contact force is increased until it reaches the lesser of the following:

6.3.4.1 120 % of the force required to achieve contact resistance of 1.0 mΩ.

6.3.4.2 2.0 kg (for standard specimen diameter).

6.3.4.3 2.0 × D/2 kg (for nonstandard specimen diameter) where D = diameter in mm.

6.3.5 Instrumentation is provided for measurement of contact force, contact current, and contact voltage. The maximum open circuit voltage shall be 10 mV and the maximum current shall be 100 mA.

6.3.6 Constant load long-term testing at the maximum force (see 6.3.3) the specimen assembly may be fixed, maintaining the contact force and the physical relationship between the specimens so as to allow controlled evaluation of the effects of long-term environmental variables, such as temperature, humidity, or gaseous ambient.

6.3.7 Constant displacement long-term testing at the maximum force (see 6.3.4), the specimen assembly may be fixed, maintaining the contact displacement and the physical relationship between the specimens so as to allow controlled evaluation of the effects of long-term environmental variables, such as temperature, humidity, or gaseous ambient under conditions whereby the contact load is influenced by stress-relaxation effects. Fixture design for constant displacement testing must be rigid and matched in thermal expansion characteristics to the material being tested, such as to maintain displacement within 1 % of the initial value for the temperature range in which it is used for the duration of the test. The rigidity requirement may be satisfied by a fixture whose spring constant (force/unit displacement) is calculated to be no less than 200× larger than the elastic spring constant of the specimen pair when fully engaged. The specimen spring constant is determined by measuring the displacement required to decrease the contact force to 1 kg from an initial 2 kg.

6.3.8 For the purpose of environmental exposure in accordance with 6.3.6 and 6.3.7, the fixturing shall be designed to maintain contact load within ±2 % over the range of applied temperature for the duration of the test. Fixturing shall be designed symmetrically so as to preclude introduction of shear forces in the plane of the specimen contact interface as temperature is changed.

6.3.9 The specific design of the apparatus may vary, provided that the functional requirements are met. A representative embodiment of a constant load crossed-wire fixture is provided in Appendix X1. For constant displacement crossed-wire testing, a variation of the stress relaxation fixture shown in Appendix X3 may be used.

6.4 Specimen contact load, current, and potential drop shall be recorded for each specimen pair as they are brought into initial contact and as the load increases. During subsequent long-term testing at constant load or constant displacement, specimen current and potential drop shall be measured at appropriate intervals, no less frequent than 1⁄10 of the duration of the test. For specimens exposed to elevated temperature, the measurements may be performed at room temperature if required to achieve the specified accuracy.

FRETTING SENSITIVITY

6.5 Specimen size and fixturing for initial engagement shall be in accordance with 6.1 – 6.3.5. Additional requirements are as follows:

6.5.1 At a maximum force as determined in 6.3.4, the specimen load shall be fixed, maintaining the contact force for the balance of the test.

6.5.2 A cyclic motion of 20 µm amplitude at the contact interface shall be imposed on one of the specimens in the direction of its longitudinal axis. The other specimen shall be held rigid. Fixture must be calibrated to assure the correct displacement at the actual contact interface between the specimens. Frequency of the applied motion shall be 1 cycle/min.

6.5.3 For the purpose of environmental exposure during the fretting sensitivity test, the fixturing shall be sufficiently resistant to the test environment so as to maintain the contact load and position (except for the applied cyclic motion) of the specimens without change for the duration of the test.

6.5.4 The specific design of the apparatus may vary, provided that the functional requirements are met. A representative embodiment is provided in Appendix X2.

6.6 The cyclic motion shall be continued until the contact resistance becomes unstable.[3]

COMPRESSIVE RELAXATION

6.7 Specimen size and fixturing for initial engagement shall be in accordance with 6.1 – 6.3.5. Additional requirements are as follows:

6.7.1 The apparatus consists of a fixture capable of performing the following functions:

6.7.1.1 Specimens are supported fully by flat or vee-groove or equivalent holders that will prevent bending due to the applied contact load. To achieve this, the specimens shall be cemented in place using a material that remains sufficiently rigid and chemically stable under applied conditions of the test to meet the requirements of 6.7.1.2. The specimen support fixture shall support the specimen for a length of 4D ± 0.5D, where D = specimen diameter and shall be centered ±0.5D with respect to the point at which the crossed specimens make contact. Beyond the load support region (at center of the specimens) the specimens shall be unsupported.

6.7.1.2 The compliance of the fixture, including the contact force measuring means, shall be designed to be no more than 5 % of the elastic spring constant of the fully loaded specimen. The specimen spring constant is determined by measuring the displacement required to decrease the contact force to 1 kg from the initial 2 kg.

6.7.1.3 The test fixture may be maintained at normal room temperature, 23 ± 3°C, or exposed to elevated temperature, as appropriate for evaluating the materials of interest with respect to the requirements for proposed applications. The fixture shall be designed to impart no more than 5 % change of contact force when changing temperature from the loading condition to the long-term dwell condition.

6.7.1.4 The specimens are brought into contact at a rate of 1 mm/min or less until contact is established. After physical contact is established, the contact force is increased at a rate of 1 kg/min until it reaches 2 kg.

6.7.1.5 The mechanical position of the specimen holders relative to one another then is fixed. The fixture must accomplish this without change in force or position. The loading mechanism may be removed once the specimen holders are fixed.

6.7.1.6 The specific design of the apparatus may vary provided that the functional requirements are met. A representative embodiment is provided in Appendix X3.

6.7.2 Contact force is measured as a function of time, maintaining the fixed relationship between the specimen holders.

7. Sampling

7.1 Sample size for each conductor material evaluated and for the reference material to which the performance is being compared, shall be as follows:

7.1.1 Minimum sample size for contact resistance tests is 10 specimens.

7.1.2 Minimum sample size for fretting sensitivity tests is 10 specimens.

7.1.3 Minimum sample size for compressive relaxation tests is 4 specimens.

8. Specimen Preparation

8.1 Specimens shall be cut from random points along a length of the conductor being evaluated.

8.2 A basic set of specimens shall be tested without chemical, abrasive, or other surface cleaning or treatment. The effect of cleaning or other surface treatment may be evaluated using additional specimen sets. If electrical insulation must be removed as part of the specimen preparation, this must be accomplished without scraping the conductor surface at (what will become) the contact point.

9. Report

9.1 A report of connectability testing according to these test method, as a minimum, shall include the information defined in this section. All nonstandard aspects of test procedure or test specimen configuration shall be noted.

9.1.1 Identification of person/organization performing the tests.

9.1.2 Date of test report.

9.1.3 Identification of conductor materials (test materials and reference materials).

9.1.3.1 Sufficient detail shall be provided to allow procurement of materials essentially identical to that tested.

9.1.4 Specimen configuration and preparation.

9.1.5 Tests performed.

9.1.5.1 Procedure.

9.1.5.2 Sample size.

9.1.5.3 Applied conditions.

[3] Braunovic M., "Effect of Fretting on the Contact Resistance of Aluminum With Different Contact Materials," Proceedings of the Ninth International Conference on Electric Contact Phenomena and the 24th Annual Holm Conference on Electrical Contacts, Illinois Institute of Technology, Chicago, 1978.

9.1.5.4 *Test Results*—Raw data plus (optional) plotted and (optional) statistical summaries comparing performance of the reference conductor to the test conductor.

9.1.5.5 Instrumentation precision and bias evaluation for electrical, force, and temperature measurements being reported.

10. Precision and Bias

10.1 Precision and bias of the individual parameter measurements depend on the particular instrumentation used in the tests and the particular design of the fixturing.

10.2 The use of reference samples for testing under these test methods eliminate many sources of bias. The comparative results obtained are considered to be free from bias caused by instrumentation and fixturing variations.

10.3 Other sources of bias, such as lot-to-lot differences in sample materials, may be detected by comparison of the results obtained with the reference conductor samples to those previously obtained on the same material at other times and by other laboratories.

11. Keywords

11.1 connectability; contact resistance; creep; electrical conductor; fretting sensitivity; stress relaxation

APPENDIXES

(Nonmandatory Information)

X1. CONSTANT FORCE CROSSED-WIRE FIXTURE

X1.1 Fig. X1.1—Increasing W brings crossed wires into contact at W_0. Flexure plate at A serves to allow crossed wires to come together but inhibits lateral motion. Increase W at required rate to reach specified force at crossed-wire contact. Calculate crossed wire contact force from the geometry.

X1.2 Fig. X1.2—After loading, the tension rod may be fixed at B by setscrew or adhesive, and W can be removed without changing the contact force. The compliance of the spring element (an extension of the flexure plate) must be designed to assure that the load remains essentially constant within the limits prescribed.

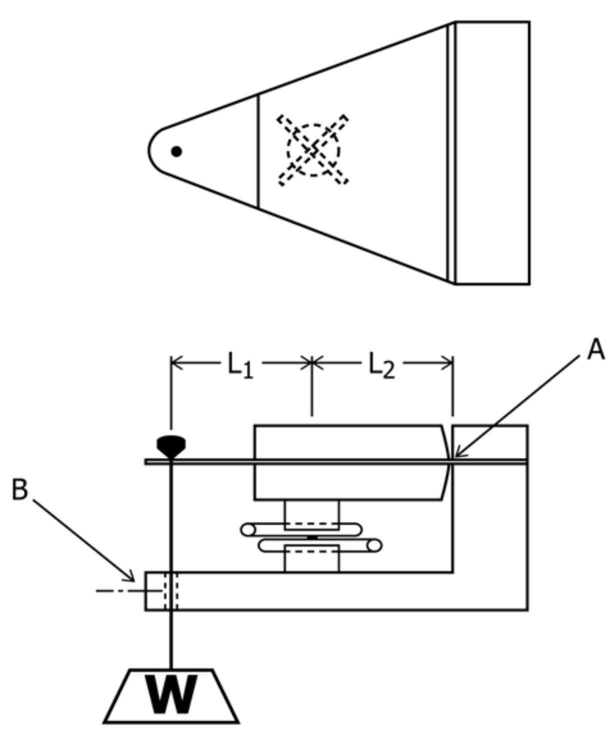

FIG. X1.1 Constant Force Crossed-Wire Fixture

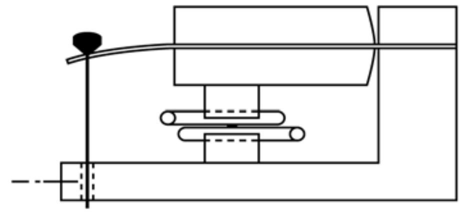

FIG. X1.2 Constant Force Crossed-Wire Fixture: Loaded Position

X2. CROSSED-WIRE FRETTING FIXTURE

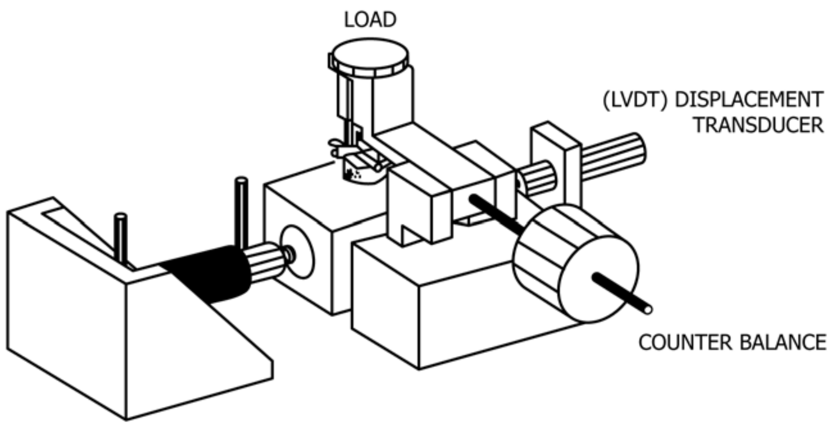

FIG. X2.1 View of a Single Fretting Station

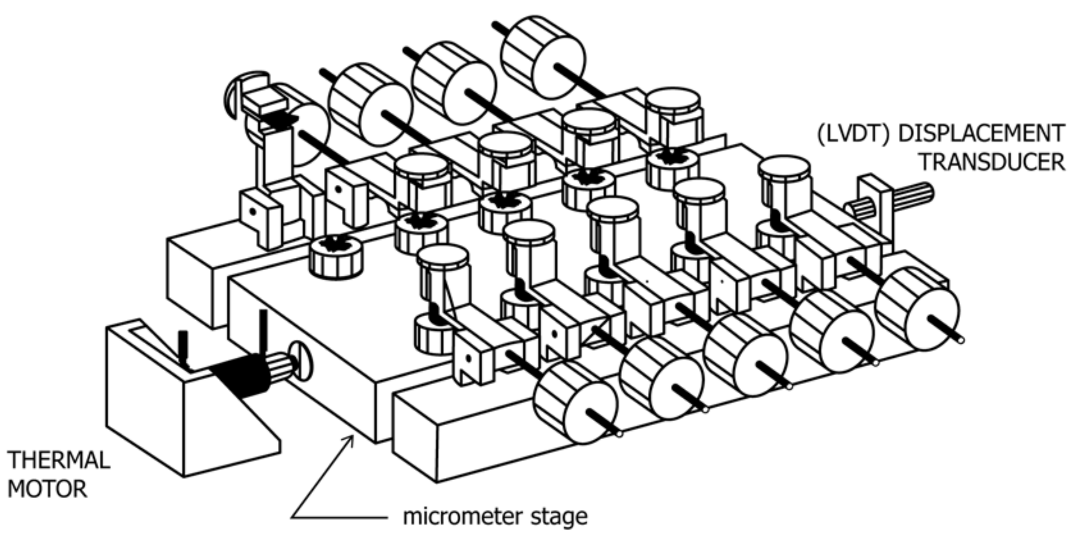

FIG. X2.2 Multi-Station Fretting Assembly Driven by a Thermal Motor

X3. STRESS RELAXATION FIXTURE

X3.1 Fig. X3.1—The main body of the fixture is suspended from a flange around the upper rim. The upper specimen holder is advanced downward until contact is made between the specimens and then the load is increased to the specified amount. The load is held until adhesive at the joint B hardens. The adhesive may be epoxy, anaerobic locking cement, CNA, or any other type that is chemically inert relative to the contact and fixture materials and can withstand the temperature of the test without softening. The external applied load is removed after the adhesive hardens.

X3.1.1 Contact load is measured by a load cell incorporated into one of the specimen holders or by strain gages on the wall of the body at A. The elasticity of this wall, or of any load cell used, must be designed carefully so as to enable the force measurements to be made while at the same time satisfying the compliance (spring rate) limitation.

X3.1.2 Holes in the fixture may be provided in the upper and lower sections to facilitate isothermal heating or cooling so as to minimize effects of thermal expansion and contraction. Careful selection of materials with respect to thermal expansion coefficient is required to maintain the dimensional relationships to within the required tolerance.

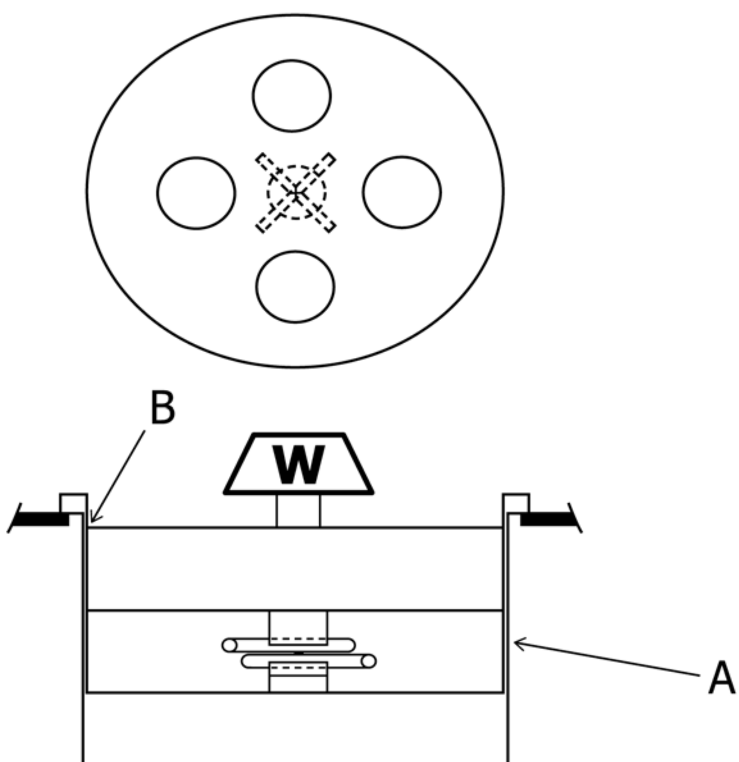

FIG. X3.1 Stress Relaxation Fixture