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Designation: E780 – 17 (Reapproved 2021)

An American National Standard

Standard Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Mineral-Insulated, Metal-Sheathed Cable at Room Temperature[1]

This standard is issued under the fixed designation E780; 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 This test method provides the procedures for measuring the room temperature electrical insulation resistance between the thermoelements and between the thermoelements and the sheath, of a mineral-insulated, metal-sheathed (MIMS) thermocouple or mineral-insulated, metal-sheathed (MIMS) thermocouple cable or between the conductors and between the conductors and the sheath, of mineral-insulated, metal-sheathed (MIMS) cable used for industrial resistance thermometers. It may be used to measure the insulation resistance of bulk lengths of mineral-insulated, metal-sheathed MIMS cable previously sealed against moisture intrusion or to test a thermocouple having an ungrounded measuring junction. This method cannot be used to test a thermocouple having a grounded measuring junction unless the measuring junction is removed prior to testing, after which the thermocouple may be dealt with in the same manner as a mineral-insulated, metal-sheathed (MIMS) cable.

1.2 This test method applies primarily to thermocouple cables and cable used for industrial resistance thermometers conforming to Specifications E585/E585M, E2181/E2181M, and E2821 and to thermocouples conforming to Specifications E608/E608M and E2181/E2181M, but may also be applied to thermocouples or MIMS cables that are suitable for use in air, whose sheath or thermoelements or conductors are comprised of refractory metals, that are tested in a dry and chemically inert environment, and that may employ compacted ceramic insulating materials other than magnesia (MgO) or alumina (Al_2O_3). Users of this test method should note that specifications dealing with compacted ceramic insulating materials other than magnesia or alumina, which are described in Specification E1652, are not currently available. As a result, acceptance criteria must be agreed upon between the customer and supplier at the time of purchase, or alternatively, judgment and experience must be applied in establishing test voltage levels and acceptable insulation resistance values for these types of thermocouples and MIMS cables.

1.3 This test method may be used for thermocouples or MIMS cables having an outside diameter of 0.5 mm (0.020 in.) or larger.

1.4 Users of this test method should be aware that the room temperature insulation resistance of a mineral-insulated, metal-sheathed thermocouple or MIMS cable will change during shipment, storage, or use if they are not properly sealed.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

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 establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E235 Specification for Type K and Type N Mineral-Insulated, Metal-Sheathed Thermocouples for Nuclear or for Other High-Reliability Applications

E344 Terminology Relating to Thermometry and Hydrometry

E585/E585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable

[1] This test method is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.14 on Thermocouples - Testing.

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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.

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E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples

E1652 Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators Used in the Manufacture of Base Metal Thermocouples, Metal-Sheathed Platinum Resistance Thermometers, and Noble Metal Thermocouples

E2181/E2181M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable

E2821 Specification for Compacted Mineral-Insulated, Metal-Sheathed Cable Used in Industrial Resistance Thermometers

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 shall apply to the terms used in this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bulk material length (BML), n*—a single length of finished thermocouple MIMS cable.

3.2.2 *dry, adj*—refers to a condition of the ambient air at time of test that does not exceed the equivalent of 50 % relative humidity at 22°C [72°F].

3.2.3 *thermocouple, n*—refers to a mineral-insulated, metal-sheathed (MIMS) thermocouple.

3.2.4 *thermocouple cable, n*—refers to a mineral-insulated, metal-sheathed (MIMS) thermocouple cable.

4. Summary of Test Method

4.1 This test method measures the room temperature (22 ± 5°C (72 ± 10°F)) dc electrical insulation resistance: *(1)* in the case of a length of MIMS cable, between each of the thermoelements or conductors and between the thermoelements or conductors and the sheath; *(2)* in the case of either a thermocouple having a single, ungrounded measuring junction or a thermocouple having multiple thermoelement pairs which share a common, ungrounded measuring junction, between the thermoelement pair(s) and the sheath; *(3)* in the case of a thermocouple having multiple, isolated, ungrounded measuring junctions, between each of the thermoelement pairs and between the thermoelement pairs and the sheath. The resistance measurements are made with an instrument such as a megohm bridge or megohmeter as described in 6.2.

4.2 In general, because removal of the measuring junction would be necessary, measurement of the insulation resistance between all thermoelements in a thermocouple is not commonly undertaken. Testing is limited to measuring the insulation resistance between the thermoelement pairs and the sheath of the thermocouple and, where possible, the thermoelement pairs.

4.3 Special preparation of a thermocouple will not normally be required, provided that the extension lead wires are clean, undamaged, and sufficiently long to permit connection of the test instrument.

4.4 A MIMS cable having effective end seals in place and its thermoelements or conductors accessible may be tested without further preparation. If preparation of the MIMS cable is required, special precautions may be necessary to prevent the intrusion of moisture and other contaminants that can affect the insulation resistance. The repeatability of the test method can primarily depend upon how well this is achieved. Preparation usually involves removing 10 to 30 mm (0.4 to 1.2 in.) of the sheath from each end of the MIMS cable, preventing the intrusion of any moisture into, or expelling any moisture from, the compacted mineral insulation, and sealing the ends with epoxy resin or other suitable moisture sealant. Users of this test method may refer to Appendix X1 for information.

5. Significance and Use

5.1 Thermocouples fabricated from thermocouple cable that has been contaminated by moisture or by other impurities may undergo large changes in thermoelectric properties or may fail catastrophically when exposed to high temperatures. Since such contamination usually lowers the electrical resistance between the thermoelements and the sheath substantially, measurement of the insulation resistance can provide a valuable check of insulation quality and cleanliness, and can serve as a basis for rejection of unsuitable material and unreliable components. For manufacturers in particular, low electrical insulation resistance can also be indicative of displaced thermoelements or conductors or defects in the metal sheath which will require further investigation, but all users should be aware of these potential defects when faced with an unacceptable insulation resistance measurement.

5.2 This test method is primarily intended for use by manufacturers and users of mineral-insulated, metal-sheathed (MIMS) thermocouples or MIMS cables to verify that measured values of insulation resistance exceed specified minimum values, such as those listed in Specifications E235, E585/E585M, E608/E608M, E2181/E2181M, and E2821. Manufacturers and users should be aware, however, that when the insulation resistance is greater than 1×10^8 Ω, disagreement by an order of magnitude in the results obtained with this test method is not unusual. In addition, users of this test method should appreciate that the room temperature insulation resistance of both MIMS cables and of finished thermocouples will change during shipment, storage, and use if the end seals are damaged or defective. Consequently, values of insulation resistance determined by this test method may not necessarily be repeatable.

6. Apparatus

6.1 Warning, all tools and apparatus used must be clean and must not introduce oil or other contaminants into the insulation. The presence of such contaminants may invalidate the test results obtained using this test method.

6.2 *Megohmeter or Megohm Bridge,* with a test voltage range between 50 and 500 VDC, measurement ranges from 1×10^5 Ω to 1×10^{12} Ω, and an accuracy of at least ±10 % of reading. Both the positive and negative connection terminals and test leads are to be electrically "floating" (not connected to earth ground potential).

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6.2.1 Other resistance-measuring instruments or circuits that satisfy the electrical requirements given in 6.2 are acceptable.

6.3 *Insulated Copper Connecting Wires,* with suitable mechanical-type connectors.

6.4 The following apparatus may be required in carrying out the procedures described in Appendix X1:

6.4.1 *Heat Source,* (for example, a small propane-type torch or an electric heat gun).

6.4.2 *Moisture Sealant,* such as epoxy resin[3], wax, or hot melt glue that when properly applied will provide an effective seal against moisture intrusion for the end(s) of the thermocouple or MIMS cable at temperatures up to 66°C (150°F). Additional sealants, with higher temperature ratings, are available. The higher temperature sealants require additional procedures to ensure a proper seal.

6.4.3 *Metal-Sheathed Cable Stripper*—Any commercially available cable stripper that will satisfactorily remove the sheath without damage to the thermoelements or conductors is acceptable.

6.4.4 *Optical Magnifier,* with a magnification of 5 to 10× (for example, a watchmaker's loupe).

7. Test Specimen

7.1 Conduct the insulation resistance measurements on the full length of mineral-insulated, metal-sheathed (MIMS) cable or on the intact thermocouple sensor assembly under test.

8. Procedure

8.1 *Resistance Measurement:*

8.1.1 If epoxy resin has been used as a sealant, make certain it has fully cured before conducting the test. Take the resistance measurements in a dry location at room temperature (22 ± 5°C (72 ± 10°F)).

NOTE 1—Surface adsorption of atmospheric moisture on the end seals may be a problem in conducting the test, and great care must be taken to ensure that the end seals are clean and dry when tests are conducted.

8.1.1.1 When insulated copper lead wires are used with a resistance measuring instrument, make sure the open-circuit resistance between the insulated wire leads is at least 1×10^{12} Ω.

NOTE 2—Large errors can arise in the measurement of high resistances due to electrical current leakage effects. Electrical resistance measurement techniques for high resistances should be used to minimize current leakage. Consult the operator's manual of the resistance measuring instrument for proper measurement techniques and safety precautions to be observed.

8.1.1.2 Adjust the resistance measuring instrument's test voltage to that specified in the invoking specification.

8.1.2 *Thermoelements or Conductors to Sheath (applies to MIMS cable and all thermocouples):*

8.1.2.1 Electrically connect all the thermoelements or conductors within the BML or all the thermoelement pairs within the thermocouple by twisting them together or mechanically short-circuiting them at the end at which the test voltage will be applied. Verify that no thermoelement, conductor, or thermoelement pair is in contact with the sheath at either end of the cable or at the cold junction. The sheath should be electrically connected to ground.

8.1.2.2 Connect the positive lead of the measuring instrument to the thermoelements or conductors or thermoelement pairs, the negative lead to the metal sheath, record the time, and energize the test circuit.

8.1.2.3 Select the lowest range of the measuring instrument that will provide an on-scale reading.

8.1.2.4 Maintain the applied test voltage until the measured value stabilizes or for a maximum time of 1 min and record the reading indicated by the measuring instrument. De-energize the test circuit, making sure that any capacitively stored electric charge has been discharged. Do not disconnect any test lead wire from either the thermoelements or conductors (or thermoelement pairs) or metal sheath without first de-energizing the measuring instrument's test circuit.

8.1.2.5 In the event of a BML or thermocouple (having more than one isolated, ungrounded measuring junction) providing an unacceptably low measurement value, individual measurements of the insulation resistance between each thermoelement, conductor, or thermoelement pair and the sheath may be required.

(1) Proceed by separating the thermoelements, conductors, or thermoelement pairs so that they are not in electrical contact with each other or with the sheath. The sheath should be electrically connected to ground.

(2) Connect the positive lead of the measuring instrument to one of the thermoelements, conductors, or one of the thermoelement pairs, the negative lead to the metal sheath, record the time, and energize the test circuit. Proceed as directed in 8.1.2.3 and 8.1.2.4.

(3) Repeat the procedure described in 8.1.2.5*(2)* for each of the thermoelements or conductors within the BML or for each of the thermoelement pairs within the thermocouple under test.

NOTE 3—Use of certain compacted ceramic insulating materials, other than magnesia or alumina, may result in insulation resistance measurements that differ significantly depending upon the polarity of the applied test voltage. In these cases, the procedures described in 8.1.2.2 – 8.1.2.5*(3)* should be repeated using the opposite polarity connections and a second set of test results recorded.

8.1.3 *Thermoelement to Thermoelement or Conductor to Conductor (applies only to a MIMS cable):*

8.1.3.1 Separate the thermoelements or conductors so that they are not in electrical contact with each other or with the sheath. The sheath should be electrically connected to ground.

8.1.3.2 Make electrical connections to any two thermoelements or conductors from the test voltage terminals of the measuring instrument with the positive and negative lead wires.

8.1.3.3 Record the time and energize the test circuit.

8.1.3.4 Select the lowest range of the measuring instrument that will provide an on-scale reading.

[3] Devcon "5-Minute" Epoxy has been found suitable for this purpose. The sole source of supply of the Devcon "5-Minute" Epoxy known to the committee at this time is Devcon Corp., Endicott St., Danvers, MA 01923. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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8.1.3.5 Maintain the applied test voltage until the measured value stabilizes or for a maximum time of 1 min and record the reading indicated by the measuring instrument. De-energize the test circuit, making sure that any capacitively stored electric charge has been discharged. Do not disconnect any test lead wire from either of the thermoelements or conductors without first de-energizing the measuring instrument's test circuit.

8.1.3.6 In the case of multiple pairs of thermoelements or multiple conductors contained in the BML, repeat the procedures described in 8.1.3.2 – 8.1.3.5 for each thermoelement pair or each conductor so that the electrical insulation resistance between each thermoelement or conductor and every other thermoelement or conductor has been measured and recorded.

8.1.4 *Thermoelement Pair to Thermoelement Pair (applies only to a thermocouple having more than one thermoelement pair which do not share a common, ungrounded measuring junction):*

8.1.4.1 Separate the thermoelement pairs so that they are not in electrical contact with each other or with the sheath. The sheath should be electrically connected to ground.

8.1.4.2 Make electrical connections to any two thermoelement pairs from the test voltage terminals of the measuring instrument with the positive and negative lead wires.

8.1.4.3 Record the time and energize the test circuit.

8.1.4.4 Select the lowest range of the measuring instrument that will provide an on-scale reading.

8.1.4.5 Maintain the applied test voltage until the measured value stabilizes or for a maximum time of 1 min and record the reading indicated by the measuring instrument. De-energize the test circuit, making sure that any capacitively stored electric charge has been discharged. Do not disconnect any test lead wire from either of the thermoelement pairs without first de-energizing the measuring instrument's test circuit.

8.1.4.6 Repeat the procedures described in 8.1.4.2 – 8.1.4.5 for each thermoelement pair so that the electrical insulation resistance between each thermoelement pair and every other thermoelement pair has been measured and recorded.

NOTE 4—Use of certain compacted ceramic insulating materials, other than magnesia or alumina, may result in insulation resistance measurements which differ significantly depending upon the polarity of the applied test voltage. In these cases, the procedures described in 8.1.3.2 – 8.1.3.6 or 8.1.4.2 – 8.1.4.6 should be repeated using the opposite polarity connections and a second set of test results recorded.

9. Report

9.1 Report the following information:

9.1.1 Date and time the test was conducted;

9.1.2 Identification of the thermocouple or bulk material length, to include its nominal dimensions (length and outside diameter), the type of sheath, type of insulation, and the number and type of thermoelement pairs, thermoelements, or conductors;

9.1.3 Brief description of the resistance measuring instrument used, including its manufacturer, model number, serial number, and accuracy;

9.1.4 The applied test voltage used for the resistance measurements;

9.1.5 For thermocouples, the insulation resistance values between each thermoelement pair (if applicable) and between the thermoelement pairs and the sheath; for MIMS cable, the insulation resistance values between each thermoelement and every other thermoelement and between the thermoelements and the sheath, or the insulation resistance values between each conductor and every other conductor and between the conductors and the sheath; and

9.1.6 Ambient temperature and relative humidity during the test period.

10. Precision and Bias

10.1 Precision and bias for this test method have not been established. When an insulation resistance test at room temperature is prescribed as a purchasing stipulation, both parties should agree to the test's parameters, and should be aware that disagreement by an order of magnitude is not unusual. See 5.2.

11. Keywords

11.1 insulation resistance; mineral-insulated, metal-sheathed (MIMS) thermocouple cable insulation resistance; mineral-insulated, metal-sheathed thermocouple insulation resistance

APPENDIX

(Nonmandatory Information)

X1. PREPARATION OF A MIMS CABLE HAVING DEFECTIVE END SEALS OR HAVING A LOW INSULATION RESISTANCE VALUE

X1.1 If the BML to be tested has the thermoelements or conductors at both its ends readily accessible, and has been fitted with end seals which are in good condition (that is, no cracks, voids, or air pockets visible when inspected with an optical magnifier that has a magnification of 5 to 10×), further preparation may not be necessary and the tests may be conducted in accordance with 8.1. However, should a defective end seal be found, or unacceptable results be obtained upon completion of the procedures described in 8.1, the procedures described in X1.1.1 may be carried out, with the consent of the party requesting the test, prior to repeating the procedures of 8.1.

X1.1.1 Complete the procedures described in X1.1.1.1 – X1.1.1.4 in a dry location at room temperature within 1 min.

NOTE X1.1—Magnesia, and to a lesser extent alumina, are hygroscopic.

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Moisture absorption from the ambient atmosphere will degrade the insulation resistance by several orders of magnitude or more with exposure of only a few minutes.

X1.1.1.1 If an end seal is present, remove the seal and a 10 to 30 mm (0.4 to 1.2 in.) length of the metal sheath from one end of the BML. A metal-sheathed cable stripper (commercially available) is recommended for removing the sheath. If a seal was not present and the BML had been subject to moisture or other contamination during transit or storage, cut at least 1 m (3 ft) off of the end of the BML before stripping off the sheath to expose the thermoelements or conductors. This should ensure that any moisture contamination of the compacted mineral insulation at the end of the BML being prepared has been removed prior to the test.

NOTE X1.2—Other sheath removal methods are acceptable, provided a clean sheath removal (that is, one that does not contaminate the insulation nor reduce the effective cross-sectional insulation spacing dimensions) is made.

X1.1.1.2 Remove the exposed compacted mineral insulation surrounding the thermoelements or conductors. Where thermoelement or conductor size permits, clean each thermoelement or conductor of any residual mineral insulation to ensure good electrical contact between each thermoelement or conductor and the measuring instrument's test leads. Micro-blasting with alumina oxide or other insulating refractory metal powder or polishing with fine sandpaper or emery cloth has been found effective in removing the insulation film from the thermoelements or conductors.

X1.1.1.3 Separate the thermoelements or conductors so that they are not in electrical contact with each other or with the sheath. Tap the end of the metal sheath to remove any loose mineral insulation.

X1.1.1.4 Provided the compacted mineral insulation has been protected against contamination and absorption of atmospheric moisture, seal the exposed end of the BML immediately by applying a moisture sealant of epoxy resin or other suitable compound. Make sure the sealant completely covers all exposed magnesia or alumina at the end of the BML but leaves the tips of the exposed thermoelements or conductors free of the sealant.

(1) If the compacted mineral insulation has been permitted to absorb moisture, the insulation resistance of the BML will be lowered. It may be possible to expel the moisture from the end of the BML by drying the BML for 12 h in an oven set at 150°C (300°F) or higher or by directly heating the exposed end of the BML. The effectiveness of either drying technique will be determined by the relative humidity level of the atmosphere to which the BML had been exposed and by the time of exposure.

(a) Heat the exposed end of the BML with a heat source to remove the moisture introduced as a result of the procedures described in X1.1.1.1 – X1.1.1.3. Starting approximately 75 mm (3 in.) from the exposed end and moving toward it, move the heat source slowly along the sheath. Repeat this process until the entire 75 mm (3 in.) end portion attains a temperature of 200 to 300°C (392 to 572°F). The intention of the heating procedure is to drive any moisture contamination resulting from exposure to the air out of the compacted mineral insulation and not further into it.

(2) Be careful to allow the end of the BML to cool sufficiently prior to applying the epoxy resin or other sealant so as to prevent damage to the epoxy resin or sealing compound employed.

X1.1.1.5 If epoxy resin was used, cure the applied epoxy resin in accordance with the epoxy manufacturer's instructions. Do not handle the end seal with bare hands. Keep the seal clean and dry.

X1.1.1.6 If an end seal is present at the other end of the BML, remove it and immediately prepare the end by following the procedures described in X1.1.1.1 – X1.1.1.5. Alternatively, some users may choose to proceed to X1.1.1.8 to avoid unnecessarily removing an end seal which may be in good condition.

X1.1.1.7 If a seal is not present at the other end of the BML, and the BML had been subject to moisture or other contamination during transit or storage, cut at least 1 m (3 ft) off of this end of the BML before stripping off the sheath to expose the thermoelements or conductors. This should ensure that any moisture contamination of the compacted mineral insulation at the end of the BML being prepared has been removed prior to the test. Repeat the procedures described in X1.1.1.2 – X1.1.1.5.

X1.1.1.8 Allow the seals at both ends of the BML to cool and, in the case of using epoxy resin, to cure completely. Inspect both of the seals for defects using an optical magnifier that has a magnification of 5 to 10×. If any cracks, air pockets, or voids are observed, consider the seal defective. Remove the defective seal and a 100 to 125 mm (4 to 5 in.) length of metal sheath adjacent to it, and prepare a new seal by repeating the procedures in X1.1.1.2 – X1.1.1.5.

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