Designation: E2821 – 20

Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed Cable Used in Industrial Resistance Thermometers[1]

This standard is issued under the fixed designation E2821; 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 specification covers the requirements for compacted, mineral-insulated, metal-sheathed (MIMS) cables used to manufacture metal-sheathed, industrial resistance thermometers referred to in this document as Resistance Temperature Detectors or RTDs.

1.2 The materials of construction include copper, nickel-clad copper, copper-45 % nickel (constantan), or nickel conductors, an austenitic stainless steel or nickel-chromium alloy sheath, and either magnesia (MgO) or alumina (Al_2O_3) insulation.

1.3 The cable diameter is between 0.093 and 0.500 in. (2.33 and 12.70 mm) and contains between two and eight conductors, set in various design configurations and wire spacings.

1.4 The values of temperature in this specification are based on the International Temperature Scale of 1990 (ITS-90).

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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 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 The latest issues of the following documents form a part of this specification to the extent specified herein. In the event of a conflict between this specification and other specifications referenced herein, this specification shall take precedence.

2.2 Due to the similarity between Compacted MIMS Thermocouple Cable and Compacted MIMS Cable used in Industrial Resistance Thermometers, some Thermocouple ASTM Standards may apply.

2.3 *ASTM Standards:*[2]

A213/A213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

A249/A249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A632 Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service

E112 Test Methods for Determining Average Grain Size

E344 Terminology Relating to Thermometry and Hydrometry

E780 Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Mineral-Insulated, Metal-Sheathed Cable at Room Temperature

E839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable

E1137/E1137M Specification for Industrial Platinum Resistance Thermometers

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

[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.03 on Resistance Thermometers.

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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.

2.4 *ANSI Standard:*[3]
ANSI B46.1 Surface Texture, Surface Roughness, Waviness and Lay

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 shall apply to this specification.

3.2 *Definitions:*

3.2.1 *lot, n*—a quantity of finished MIMS RTD cable manufactured from tubing from the same heat, wire from the same spool and heat, and insulation from the same batch, then assembled and processed together under controlled production conditions to the required final outside diameter.

3.2.2 *raw material, n*—tubing, insulation, and wires used in fabrication of MIMS RTD cable.

4. Significance and Use

4.1 MIMS RTD cable may be used as follows:

4.1.1 As a cable for attaching the sensing element to a sensor termination within a thermometer (see Specification E1137/E1137M).

4.1.2 As an extension cable connecting a thermometer to another device.

5. Ordering Information and Basis for Purchase

5.1 The purchasing documents shall specify the following options:

5.1.1 The total length of finished MIMS RTD cable or the length of each piece of finished MIMS RTD cable.

5.1.2 The material and number of conductors (see Fig. 1) and the allowable variation in conductor resistances if other than that specified in 6.2. Consult individual manufacturers for the number of conductors which are limited by cable size.

5.1.3 The sheath material (see 7.3) and whether it shall be seamless or welded and drawn. Note that other sheath material may be used with purchaser and producer agreement

5.1.4 The nominal outside diameter of the sheath (see 6.3).

5.1.5 The insulating material (either MgO or Al_2O_3) and its respective type (see 7.2). Note that other insulation composition and impurity levels may be used with purchaser and producer agreement.

5.1.6 The seal to be applied to the exposed insulation at the cable end(s) prior to shipment (see 11.1).

5.1.7 Supplementary testing or material requirements (see Supplementary Requirements).

5.1.8 Any deviations from this specification or the referenced documents.

5.1.9 The Optional Clearance if applicable (see Fig. 1).

6. General Requirements

6.1 *MIMS RTD Cable*—Cable shall be in accordance with this specification (see Fig. 2). Fig. 2 shows a cable with two conductors, but more than two conductors may be specified.

6.2 *Conductor Resistance Match*—The resistance of each conductor shall be measured. The difference between the maximum conductor resistance and minimum conductor resistance shall not exceed 10 % of the minimum conductor resistance.

6.3 *Dimensions*—The dimensional and tolerance requirements for sheath diameter and wall thickness, conductor diameter, and insulation thickness depicted in Fig. 2 and summarized in Table 1 shall be based on the nominal sheath outside diameters. The purchaser need only specify the cable's outside diameter and number of conductors required in the ordering documents. The preferred cable sizes are listed in Table 2. For any nominal sheath size:

6.3.1 The outside diameter tolerance, *A*, shall be ±0.001 in. (0.025 mm) or ±1 % of the outside diameter, whichever is greater.

6.3.2 The wall thickness, *B*, shall be at least 8 % of the nominal sheath outside diameter and shall be uniform within 1.6 % of the minimum sheath outside diameter.

6.3.3 The conductor diameter, *D*, shall be at least 8 % of the nominal sheath outside diameter.

6.3.4 The insulation thickness, *C*, either between conductors or between any conductor and the inside surface of the sheath, shall be at least 4 % of the nominal sheath outside diameter.

6.3.5 An optional clearance "*F*" (see Figs. 1 and 2) may be specified when the material between the conductors will be removed to allow for the installation of a sensing element. This construction is used when manufacturing Platinum Resistance Thermometers (PRTs) using this cable. Unless otherwise specified, the other dimensional requirements shall be maintained. Consult the cable manufacturer regarding this optional feature.

6.3.6 Dimensions shall be measured in accordance with Test Methods E839.

6.4 *Materials*—The RTD cable shall be fabricated from component parts specified in Section 7.

6.5 *Insulation Resistance at Room Temperature*—The minimum insulation resistance between conductors and between each conductor and the sheath (at room temperature) shall be as

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

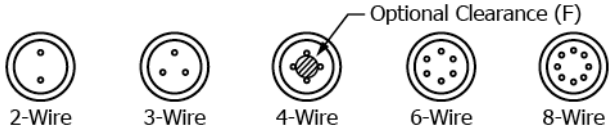

FIG. 1 Examples of Conductor Wire Configurations

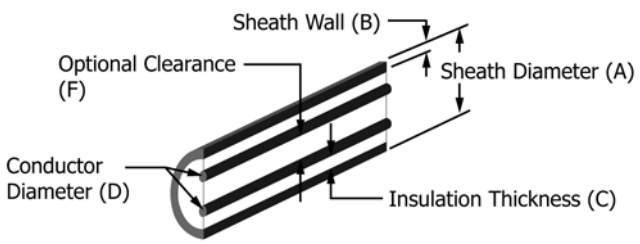

FIG. 2 Sheathed RTD Material Construction

TABLE 1 Summary of RTD Cable Dimensional Requirements (Percentage of Outside Diameter)

	2, 3, 4, 6, or 8 Wires
Minimum Sheath Thickness "B"	8 %
Minimum Conductor Diameter "D"	8 %
Minimum Insulation Thickness "C"	4 %
Optional Clearance "F"	25 %

TABLE 2 Dimensions of Metal Sheathed RTD Cable in SI and Inch-Pound Units

Preferred Sizes—Nominal Outside Diameter "A"	
mm	in.
3.00	0.125
4.50	0.188
6.00	0.250
8.00	0.313
9.50	0.375

specified in Table 3 when tested in accordance with Test Method E780 for the voltages noted. The values of insulation resistance, shall apply to the supplied lengths.

6.6 *Minimum Insulation Density*—The minimum density of the compacted mineral oxide insulation shall exceed the value which represents 70 % of the maximum theoretical density of the material. This 70 % value is 0.090 lb/in.^{3} (2506 kg/m^3) for MgO, and 0.101 lb/in.^{3} (2780 kg/m^3) for Al_2O_3.[4] See also Supplementary Requirement S5.

6.7 *Sheath Condition*—The sheath shall be free of visible surface contaminants and oxidation and shall be annealed to the extent that the conductors will permit. Tests for proving conformance are in Supplementary Requirement S2 or S8.

6.8 *Sheath Integrity*—The sheath of the finished RTD cable shall exclude gases and liquids. There shall be no holes, cracks, or other void defects that penetrate through the sheath wall. Tests for proving conformance to this requirement are in Supplementary Requirement S3.

6.9 Additional optional requirements are listed in the Supplementary Requirements section and may be included in the purchasing documents, if desired by the purchaser.

7. Material Requirements

7.1 *Conductors:*

7.1.1 The conductors shall be solid, round wire of copper, nickel, nickel clad copper, or copper-45 % nickel (constantan) with maximum operating temperatures as specified in Table 4.

[4] Handbook of Chemistry and Physics, Chemical Rubber Publishing Co., No. 76 (1995) edition.

TABLE 3 Room Temperature Insulation Resistance Requirements in SI and Inch-Pound Units

Nominal Sheath Outside Diameter	Applied Voltage Minimum VDC	Insulation Resistance (Megohms) Minimum
Less than 3.2 mm	500	5000
3.2 mm and larger	500	10 000
Less than 0.125 in.	500	5000
0.125 in. and larger	500	10 000

TABLE 4 Recommended Maximum Conductor Operating Temperatures

Conductor Type	°C	°F
Copper	250	482
Nickel Clad Copper	400	752
Nickel 201	650	1200
Copper-45 % Nickel (Constantan)	650	1200

7.1.2 All conductors used in a specific cable shall be from the same lot of material in order to minimize the generation of spurious Electromotive Forces (EMFs) when placed in a temperature gradient.

7.1.3 Prior to assembly, the producer shall verify that all conductors used are free of visible surface oxides, scale and contaminates such as drawing compounds, carbon, dirt and dust. The absence of scale and contaminants can be verified by wiping the wire with a solvent-saturated lint-free cloth. Acetone, isopropyl alcohol, methanol, and ethanol are all acceptable solvents. A light discoloration of the cloth is acceptable unless particles of grit or metal flakes are visually detectable without use of magnification. If acetone or any other solvent that may leave a residual film is used for initial cleaning, a final cleaning with an acceptable cleaning solvent, such as isopropyl alcohol, shall be performed.

7.2 *Insulation:*

7.2.1 The insulation shall be magnesia (MgO) or alumina (Al_2O_3) conforming to Specification E1652.

NOTE 1—Other insulation composition and impurity levels may be used with purchaser and producer agreement.

7.3 *Sheath Material:*

7.3.1 The sheath material shall be austenitic stainless steel, or heat-resistant nickel-chrome alloy. If tubing is used, either seamless or welded is acceptable.

7.3.2 Alternate heat-resistant tubing materials may be specified for the sheath by the producer provided the annealing requirements imposed by 6.7 are satisfied.

7.3.3 Prior to assembly, the producer shall verify that each piece of sheath material used in the fabrication of RTD cable is free of visible surface oxides, scale and contaminants such as drawing compounds, carbon, dirt, and dust. The absence of scale and contaminants can be verified by passing a solvent-saturated swatch of lint-free yarn or cloth against the inner surface of the sheath material. Acetone, isopropyl alcohol, methanol and ethanol are all acceptable solvents. A light discoloration of the swatch or plug is acceptable unless particles of grit or metal flakes are visually detectable without the use of magnification. If acetone or any other solvent that leaves a harmful residual film upon evaporation is used for initial cleaning, a final cleaning with an acceptable cleaning solvent, such as isopropyl alcohol, shall be performed.

8. Processing Requirements

8.1 The producer shall be responsible for raw materials and all processing to ensure that the overall requirements of this specification are met.

9. Quality Verification and Test Requirements

9.1 The following tests are required for all MIMS RTD cable furnished under this specification:

9.1.1 Dimensional inspection (see 6.3).

9.1.2 Insulation resistance at room temperature (see 6.5).

9.1.3 Comparison of Conductor Resistances (see 6.2).

9.2 *Documentation*—Certificate of conformance in accordance with Section 10.

9.3 Optional testing is defined in the Supplementary Requirements section. If the purchaser desires that these tests be performed in whole, or in part, they shall so state in the purchasing documents.

9.4 *Standard Tests*—The producer shall perform an inspection and tests in accordance with Table 5, using the methods delineated in Test Methods E839. Sampling shall be performed from each lot.

9.5 *Dimensional Inspection*—The producer shall measure a sample of finished RTD cable to determine conformance to 6.3 for the following: outside diameter, conductor diameter, sheath wall thickness, and insulation thickness. Dimensions shall be measured in accordance with Test Methods E839.

9.6 *Insulation Resistance at Room Temperature*—The insulation resistance of each length of cable shall be tested to determine conformance to Table 3 and 6.5.

9.7 *Conductor Resistance Verification*—The electrical resistances of each conductor within the cable shall be measured to ensure that they comply with 6.2.

10. Certification and Reports

10.1 A certificate of conformance covering the completed MIMS RTD cable and the data taken during the testing by the producer shall be provided to the purchaser upon request. The certificate shall state that the product has been manufactured from materials specified in the purchase order, that the material was tested in accordance with this specification, that the results are in accordance with this specification, and that the test data and certifications are on file at the producer's facility. It is suggested that these records be retained for a minimum of three years.

TABLE 5 Standard Tests

Section	Test	Test Piece
9.1.1 and 9.5	Dimensional Inspection	Sample
9.1.2 and 9.6	Insulation Resistance at Room Temperature	All (A)[A]
9.1.3 and 9.7	Conductor Resistance Match	All (A)[A]

[A] "A" = Each length of finished RTD cable shall be tested.

11. Packaging, Marking, and Shipping

11.1 *Sealing*—All open ends of MIMS RTD cable shall be sealed, when processing allows, prior to placing in inventory or shipment, in order to prevent entry of moisture inside the cable. Seal welding, melted plastic, and epoxy seals are examples of acceptable sealing techniques (see 5.1.6).

11.2 *Cleaning Prior to Packaging*—The outer sheath shall be cleaned free of grease, oil, dirt, and other foreign substances.

11.3 The method of packaging of the completed cable shall be in accordance with the producer's usual practice, unless otherwise requested by the purchaser.

11.4 Each individual length of product shall be marked with the producer's name, unique lot identification number, cable diameter, number of conductors, conductor material, sheath material, insulation material, and the purchaser's order number.

11.5 Each shipping container shall be legibly marked with at least the following information:

11.5.1 Producer's name and address,

11.5.2 Length of each piece of finished cable and the quantity of cables in the package,

11.5.3 Purchaser's order number,

11.5.4 Nominal diameter of cable,

11.5.5 Sheath material,

11.5.6 Insulation material and type (if required), and

11.5.7 Conductor material and number of conductors.

12. Keywords

12.1 alumina; compacteds; conductors; constantans; copper-45 % nickels; coppers; industrial resistance thermometers; magnesia; Metal Sheatheds; MIMS; Mineral-Insulateds; nickels; nickel plated coppers; RTD cables

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Optional Elevated-temperature Insulation Resistance

S1.1 If this optional requirement is specified, insulation resistance shall be measured at 1202 °F (650 °C) to indicate whether or not insulation contamination, which cannot be detected at room temperature, is present. This test is intended primarily for high-temperature RTD service. This is a destructive test, and material tested for high-temperature insulation resistance shall not be considered usable. Perform this high-temperature insulation resistance test in accordance with subsection 7.5.2 of Test Methods E839. The insulation resistance requirements are shown in Table S1.1. This test is only available for conductor material that is suitable for 650 °C service in accordance with Table 4.

NOTE 2—At elevated temperatures, such as 650 °C, insulation resistance is inversely proportional to the length in the elevated temperature.