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Standard Specification for Tungsten-Rhenium Alloy Thermocouple Wire[1]

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1. Scope

1.1 This specification covers the requirements for bare, solid conductor, tungsten and rhenium alloy thermoelements having diameters of 0.13 mm (0.005 in.) to 0.5 mm (0.020 in.) supplied in matched pairs. These thermoelements shall be suitable for use either in bead-insulated, bare-wire thermocouples, or in compacted metal-sheathed, ceramic insulated thermocouple material or assemblies.

1.2 This specification covers the thermocouple combinations of tungsten-3 % rhenium versus tungsten-25 % rhenium (W3RE/W25RE) and tungsten-5 % rhenium versus tungsten-26 % rhenium (W5RE/W26RE). All information applies to both combinations unless otherwise noted.

1.3 It is recognized that the alloys described are refractory and are not suitable for use at high temperatures in non-inert atmospheres. All tests and processes described herein must be performed under suitably inert conditions that are non-reactive to tungsten-rhenium alloys.

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

2. Referenced Documents

2.1 *ASTM Standards:*

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[1] This specification is under the jurisdiction of ASTM Committee E-20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

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E 8 Test Methods ~~of~~ for Tension Testing of Metallic Materials[2]
E 207 Test Method ~~o~~ for Thermal EMF Test of Single Thermoelement Materials by Comparison with a ~~Secondary Standard~~ Reference Thermoelement of Similar EMF-Temperature Properties[3]
E 220 Test Method for Calibration of Thermocouples by Comparison Techniques[3]
E 344 Terminology Relating to Thermometry and Hydrometry[3]
E 452 Test Method for Calibration of Refractory Metal Thermocouples Using an Optical Pyrometer[3]
E 988 Temperature-Electromotive Force (EMF) Tables for Tungsten-Rhenium Thermocouples[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions used in this standard, see Terminology E 344.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dope, vt*—in this specification, to add potassium, silicon and aluminum compounds to the alloy powders during the preparation to produce a ductile wire. See NASA CR-72884.[4]

3.2.2 *Discussion*—Alloy powders are doped.

4. Ordering Information

4.1 A purchase order for thermocouple material conforming to this specification should specify the following:

4.1.1 *Thermocouple Wire Composition*— May be doped W3RE/W25RE or doped W5RE/W26RE.

4.1.2 *Wire Size*—Specify size with each order.

4.1.3 *Wire Length*—Specify total amount of each wire and minimum continuous length.

4.1.4 *Thermocouple Calibration*—Paired wires shall be furnished to the initial calibration tolerances stated in 5.1.4.2 unless otherwise requested.

4.1.5 *Required Mechanical Properties*— See 5.1.3.

4.1.6 *Instructions for Spooling, Packaging, and Labeling*—Wires shall be supplied on spools of a nominal 100 mm (4-in.) diameter core and boxed individually, unless otherwise requested. Each spool shall be marked to identify the wire composition, diameter, quantity, processor's name, spool designation and customers purchase order number in a manner to identify the pair of wires to be used to form a thermocouple meeting the calibration requirement.

4.1.7 *Tests and Certifications Required from the Processor*—Unless otherwise requested, the processor shall supply a certificate with each order stating the wire composition, size and calibration information.

5. Materials and Manufacture

5.1 *Thermocouple Wire*:

5.1.1 *General*—The thermoelements shall be tungsten-3 % rhenium and tungsten-25 % rhenium or tungsten-5 % rhenium and tungsten-26 % rhenium, as indicated on the purchase order.

5.1.2 *Physical*:

5.1.2.1 The diameter of each wire shall be uniform end-to-end to within 0.01 mm (0.0005 in.) for 0.5 mm (0.02 in.) diameter wire and smaller.

5.1.2.2 The wires shall be solid, round, smooth and be free of weld joints, slivers, kinks, pits or nicks exceeding 5 % of diameter.

5.1.2.3 The wire surface shall be uniformly clean and free of discoloration.

5.1.2.4 The thermoelements shall be heat treated to provide the specified ductility of 5.1.3.1.

5.1.2.5 Mechanical or optical methods may be used to verify the requirements of 5.1.2.1, 5.1.2.2, and 5.1.2.3.

5.1.3 *Mechanical*:

5.1.3.1 The wires shall have an elongation measured at a temperature in the range of 20 to ~~35°C (70~~ 35 °C (68 to 95 °F) of at least 12 % as measured over a 50 mm (2 in.) gage length.

5.1.3.2 Elongation shall be determined in accordance with Test Methods E 8 using a rate of 0.2 mm/mm/min. (0.2 in./in./min.) maximum and a 50 mm (2-in.) gage length.

5.1.3.3 The wires shall withstand, at a temperature of 20 to 35 °C (68 to 95 °F), wrapping five turns around a mandrel five times the diameter of the wire without breaking or splitting.

5.1.3.4 The tests shall be made on at least one specimen from each end of any continuous length of wire.

5.1.4 *Thermoelectric*:

5.1.4.1 The emf versus temperature characteristics of the matched thermoelements shall be determined using procedures described in Test Methods E 207, E 220 or E 452.

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 14.03.

[4] NASA CR-72884, "Some Studies on Behavior of W-Re Thermocouple Materials at High Temperatures." Available from National Aeronautics and Space Administration, 400 Maryland Ave. S.W., Washington, DC 20546.

5.1.4.2 The emf versus temperature relationship of the matched pair of thermoelements shall comply with the values shown in Tables E 988 for the alloy pair being used.

5.1.4.3 The initial calibration tolerance shall be ±1 % of actual temperature 400 to 2315 °C (752 to 4200 °F) for W3 %RE/W25 %RE and ±1 % of actual temperature 426 to 2315 °C (800 to 4200 °F) for W35 %RE/26 %RE.

5.1.4.4 The wires shall be thermoelectrically homogeneous so that when joined to form a thermocouple whose measuring junction and reference junction are held at constant temperatures, any short-term (less than 1 h) change in the temperature profile along the wire within the range from 0 to 1000 °C (32 to 1832 °F) will not produce a change in the thermocouple output signal of more than 100 µV.

5.1.5 *Electrical*:

5.1.5.1 A dc resistance measurement may be used to verify mechanical integrity of tungsten-rhenium alloy wires having diameters of 0.125 mm (0.005 in.) or larger. Defects cited in 5.1.2.2 can cause high local resistance in tungsten alloy wires.

5.1.5.2 A dc resistance measurement at 20 °C (68 °F) shall be made on an accurately measured reference length of each thermoelement using an instrument and range to yield ±1 % accuracy to derive a resistance per meter or foot. The wire size of the reference length and test pieces of known, practical lengths should be within 0.005 mm (0.0002 in.) of each other.

5.1.5.3 The resistance measurement taken according to 5.1.5.2 shall be compared to the dc resistance measurements of each measured full length of wire.

5.1.5.4 The full length resistance per unit length (ohms per meter or foot) of each of the test lengths shall be within 10 % of the value obtained from the reference length.

NOTE 1—The resistivity of W25RE and that of W26RE is more than double that of either W3RE or W5RE, and all of these alloys have high temperature coefficients of resistance.

5.2 *Composition*:

5.2.1 *Positive thermoelement*:

5.2.1.1 The positive thermoelement for the W3RE/W25RE combination shall have a nominal composition of 97 % tungsten and 3 % rhenium.

5.2.1.2 The positive thermoelement for the W5RE/W26RE combination shall have a nominal composition of 95 % tungsten and 5 % rhenium.

5.2.1.3 The positive thermoelement shall be doped by the addition of potassium, silicon, and aluminum compounds or otherwise stabilized by the addition of volatile substances that promote desirable grain structure and workability and maintain ductility after high temperature use.

5.2.2 Negative thermoelement:

5.2.2.1 The negative thermoelement for the W3RE/W25RE combination shall have a nominal composition of 75 % tungsten and 25 % rhenium.

5.2.2.2 The negative thermoelement for the W5RE/W26RE combination shall have a nominal composition of 74 % tungsten and 26 % rhenium.

6. Lot Identification

6.1 Thermocouple wires, test results and certifications shall be identified by manufacturer's lot or batch number. Wires processed or heat-treated by a wire processor and tested as a batch shall be identified uniquely.

7. Lot Designation

7.1 A vendor who purchases wire from processors for repackaging and resale shall supply, for each spool, the wire processor's name, lot designation and certification to the customer.

8. Extension Wires

8.1 Due to the high cost of tungsten-rhenium alloys, to difficulties encountered in obtaining long continuous lengths of these alloys and to inherent problems in applications where ductility is important, many users find it advantageous to use compensating extension wires made of base metal alloys.

8.2 Information on upper temperature limits and the suppliers guaranteed limits of error for currently available compensating extension wires for W3RE/W25RE and for W5RE/W26RE can be found in Tables E 988.

9. Keywords

9.1 rhenium; thermocouple; thermoelement; tungsten