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Standard Specification for Wire for Use In Wire-Wound Resistors[1]

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1. Scope

1.1 This specification covers round wire and ribbon with controlled electrical properties for use in wire-wound resistance units and similar applications, but not for use as electrical heating elements.

2. Referenced Documents

2.1 *ASTM Standards:*

B 63 Test Method for Resistivity of Metallically Conducting Resistance and Contact Materials [2]

B 77 Test Method for Thermoelectric Power of Electrical-Resistance Alloys [2]

B 84 Test Method for Temperature-Resistance Constants of Alloy Wires for Precision Resistors [2]

3. Significance and Use

3.1 This specification on wire and ribbon contains the generic chemistry and requirements for resistivity, temperature coefficient of resistance, thermal emf versus copper resistance tolerances, and mechanical properties of bare wire, as well as the wire enamels and insulations of alloys normally used in the manufacture of wound resistors.

4. Alloy Classes

4.1 Fifteen classes of alloys are covered by this specification as listed in Table 1.

5. Elongation

5.1 The wire shall conform to the requirements for elongation as prescribed in Table 1, when tested on a 10-in. (254-mm) length.

6. Resistivity

6.1 The bare wire shall conform to the requirements for nominal resistivity as prescribed in Table 1.

6.2 Actual resistivity shall not vary from nominal resistivity by more than ±5 % for Alloy Classes 1 to 4 inclusive, and ±10 % for Alloy Classes 5 to 11 inclusive.

7. Nominal Electrical Resistance per Unit Length

7.1 The nominal resistance per unit length for round wire shall be calculated from the nominal resistivity and the nominal cross-sectional area.

NOTE 1—When ribbon or flat wire is produced by rolling from round wire, the cross section departs from that of a true rectangle by an amount depending on the width-to-thickness ratio and the specific manufacturing practice. The conventional formula for computing ohms per foot and feet per pound is to consider the cross section as 17 % less than a true rectangle when width is more than 15 times the thickness and 6 % less than a true rectangle in other cases. This is not valid in view of modern rolling equipment and practices, but still is widely used as a basis of description. Ribbon actually is made to a specified resistance per foot, and no tolerance is specified for thickness. An alternative and a closer approximation would be that for ribbon rolled round wire, the electrical resistance would be calculated on a cross 6 % less than a true rectangle.

8. Temperature Coefficient of Resistance

8.1 The change in resistance with change in temperature, expressed as the mean temperature coefficient of resistance based on the reference temperature of 25°C, shall be within the limits specified in Table 1, Columns 4 and 6, over the corresponding temperature ranges specified in Columns 5 and 7. The mean temperature coefficient of resistance referred to 25°C is defined as the slope of a chord of an arc. This slope is determined from the following equation:

$$\alpha_m = (\Delta R / R_{25} \Delta T) \times 10^6$$

where:

α_m = mean temperature coefficient of resistance, ppm/°C, Table 1, Columns 4 and 6,
ΔR = change in resistance over temperature range indicated in Table 1, Columns 5 and 7,
R_{25} = resistance at 25°C,
ΔT = temperature range indicated in Table 1, Columns 5 and 7.

8.2 For Alloy Classes 1, 2, and 5, the temperature coefficient as specified in Table 1 of any 10-ft (3-m) length shall not vary more than 3 ppm/°C from that of any other 10-ft length on the same spool or coil.

[1] This test method is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.10 on Thermostat Metals.

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[2] *Annual Book of ASTM Standards*, Vol 03.04.

TABLE 1 Classes of Alloys and Requirements

Alloy Class [A]	Alloy Composition, approximate, %	Resistivity, Ω·cmil/ft (μΩ·m)	Mean Temperature Coefficient of Resistance, α_m ppm for °C Over Temperature Range, ΔT				Maximum Thermal emf versus Copper, mV/°C [B]		Elongation in 10 in., min, %		
				ΔT	α_m	ΔT	mV/°C	Temperature Range, ΔT [C]	Over 0.002 in. [D] in Diameter	0.002 to 0.001 in. [D] in Diameter	0.0009 in. [D] in Diameter and Finer
1	2	3	4	5	6	7	8	9	10	11	12
1a	nickel base, nonmagnetic	800 (1.330)	0, ±20	+ 25 to − 55	0, ±20	+ 25 to + 105	+ 0.003	−65 to + 250	10	5	3
1b	nickel base, nonmagnetic	800 (1.330)	0, ±10	+ 25 to − 55	0, ±10	+ 25 to + 105	+ 0.003	−65 to + 150	10	5	3
1c	nickel base, nonmagnetic	800 (1.330)	0, ±5	+ 25 to − 55	0, ±5	+ 25 to + 105	+ 0.003	−65 to + 150	10	5	3
2a	iron base, magnetic	800 (1.330)	0, ±20	+ 25 to − 55	0,± 20	+ 25 to + 105	−0.004	−65 to + 200	10	5	3
2b	iron base, magnetic	800 (1.330)	0, ±10	+ 25 to − 55	0, ±10	+ 25 to + 105	−0.004	−65 to + 150	10	5	3
3a	80 nickel, 20 chromium	650 (1.081)	+ 80, ±20	+ 25 to − 55	+ 80, ±20	+ 25 to + 105	+ 0.006	−65 to + 250	15	5	3
3b	80 nickel, 20 chromium, stabilized	675 (1.122)	+ 60,± 20	+ 25 to − 55	+ 60, ±20	+ 25 to + 105	+ 0.006	−65 to + 250	15	5	3
4	60 nickel, 16 chromium, balance iron	675 (1.122)	+ 140, ±30	+ 25 to − 55	+ 140, ±30	+ 25 to + 105	+ 0.002	−65 to + 200	15	5	3
5a	55 copper, 45 nickel	300 (0.499)	0, ±20	+ 25 to − 55	0, ±20	+ 25 to + 105	−0.045	−65 to + 150	15	5	3
5b	55 copper, 45 nickel	300 (0.499)	0, ±40	+ 25 to − 55	0, ±40	+ 25 to + 105	−0.045	−65 to + 150	15	5	3
6	manganin type	290 (0.482)	0, ±15 [E]	[E]	0, ±15 [E]	[E]	−0.003	+ 15 to + 35	15	5	3
7	77 copper, 23 nickel	180 (0.299)	+ 180, ±30	+ 25 to − 55	+ 180,± 30	+ 25 to + 105	−0.037	−65 to + 150	15	5	3
8	70 nickel, 30 iron	125 (0.199)	+ 3600, ±400	+ 25 to − 50	+ 4300, ±400	+ 25 to + 104	−0.040	−50 to + 100	15	5	3
9	90 copper, 10 nickel	90 (0.150)	+ 450, ±50	+ 25 to − 55	+ 450, ±50	+ 25 to + 105	−0.026	−65 to + 150	15	5	3
10	94 copper, 6 nickel	60 (0.100)	+ 700, ±200	+ 25 to − 55	+ 700,± 200	+ 25 to + 105	−0.022	−65 to + 150	15	5	3
11	98 copper, 2 nickel	30 (0.050)	+ 1400, ±300	+ 25 to − 55	+ 1400, ±300	+ 25 to + 105	0.014	−65 to + 150	15	5	3

[A] Alloy Classes 1a to 8 inclusive are designed to provide controlled temperature coefficients. Values shown for other classes are for information only. All values are based on a reference temperature of 25°C.

[B] Alloy Classes 1a, 1b, 1c, 2a, 2b, 3a, 4, and 6 are designed to give a low emf versus copper. Values shown for other classes are for information only. Maximum indicates the maximum deviation from zero and the plus or minus sign the polarity of the couple.

[C] The maximum temperature values listed apply to the alloy wire only. Caution should be exercised pending knowledge of the maximum temperature of use for the coating material involved.

[D] If metric sizes are desired, 1 in. = 25.4 mm.

[E] Alloy Class 6 (manganin type for resistors), has a temperature-resistance curve of parabolic shape with the maximum resistance normally located between 25 and 30°C. Thus, Columns 5 and 7 cannot indicate 25°C as a limit but α^m may be expressed as a maximum of + 15 ppm for 15°C to the temperature of maximum resistance and a maximum of − 15 ppm from the temperature of maximum resistance to 35°C. All of the information included in this note is based on measurements made in accordance with Test Method B 84.

9. Thermal EMF with Respect to Copper

9.1 The thermal electromotive force (emf) with respect to copper shall fall within the limits shown in Table 1, in the corresponding temperature ranges.

10. Permissible Variations in Electrical Resistance

10.1 The actual resistance per unit length of any wire furnished under these specifications shall not vary from the nominal resistance by more than the following amounts:

Form	Permissible Variation, ±%
Over 0.005 in. (0.127 mm) in diameter	5
0.002 to 0.005 in. (0.051 to 0.127 mm) in diameter, incl	8
Under 0.002 in (0.051 mm) in diameter	10
Ribbon	5

10.2 For Alloy Classes 1 to 4 inclusive, the actual resistance of any 1-ft length of wire in one spool or coil shall not vary by more than 3 % from the actual resistance of any other 1 ft of wire in the same spool or coil.

10.3 For Alloy Classes 5 to 11 inclusive, the actual resistance of any 1-ft length of wire in one spool or coil shall not vary by more than 5 % from the actual resistance of any other 1 ft of wire in the same spool or coil.

11. Permissible Variations in Dimensions

11.1 Permissible variations in dimensions of bare wire are not specified, since these materials are used for resistance purposes, in which the resistivity and the electrical resistance per unit length, rather than the dimensions, are of prime importance. The electrical resistance per unit length can be determined more accurately than the dimensions of very small wire.

12. Finish

12.1 The wire shall be as uniform and free from kinks, curls, and surface defects such as seams, laminations, scale, and other irregularities as the best commercial practice will permit.

13. Enamel Coatings

13.1 Enamel coatings shall include any baked-on film of insulating material, such as varnish enamel, polyurethane, vinyl acetal, etc. and shall conform to the requirements prescribed in 13.2 to 13.7.

13.2 The physical dimensions of the enamel film shall conform to the requirements specified in Table 2.

13.3 The continuity of dielectric strength of medium or heavy enamel shall show a maximum of 10 breaks/100 ft when tested with a potential of 150 V applied between a single mercury cup and the bared end of the wire. In the dielectric strength test, 100 ft of the wire shall be drawn through the mercury or equivalent at a speed that will permit the recording of 600 counts/min. The test circuit shall have a recording sensitivity of 300 000 Ω ± 20 % with 150 V across the coating. The tension on the wire shall not exceed one half of its yield strength. On agreement between the manufacturer and the