Standard Test Method for Change of Resistance With Temperature of Metallic Materials for Electrical Heating[1]

This standard is issued under the fixed designation B70; 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 covers the determination of the change of resistance with temperature of metallic materials for electrical heating, and is applicable over the range of service temperatures.

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

1.3 *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 Material Safety Data Sheet (MSDS) 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. Significance and Use

2.1 The change in resistance with temperature for heating element materials is a major design factor and may influence material selection. The measurement of this change is essential to ensure that heating elements perform as designed. This test method was designed to minimize the effect different manufacturing processes have on resistance change, thereby yielding results that are reproducible.

3. Test Specimen and Leads

3.1 The test specimen shall be prepared from material as left by the manufacturing process, and in a form suitable for measuring its resistance in an electric furnace. When the resistance is to be measured with a Kelvin bridge, potentiometer, digital ohmmeter, or equivalent, a current lead shall be welded to each end of the specimen in such a manner that there will be no change of current distribution in the specimen during measurements. Potential leads, one at each end, shall be attached by welding, at a distance from the corresponding current lead not less than one tenth of the length of the specimen between the potential leads.

3.2 When the resistance is to be measured with a Wheatstone bridge, only the current leads are required. The resistance of the leads in this case shall not exceed 1 % of the resistance of the specimen and the leads shall be made of the same type of alloy as the test specimen. For both methods of measurement, the leads shall have a length within the heated zone of the furnace of at least 50 times their minimum transverse dimension, in order to avoid disturbance of the temperature of the specimen by conduction of heat to the colder parts of the furnace.

4. Electric Furnace

4.1 The furnace for heating the specimen shall be of such a type that the temperature can be controlled over the range from room temperature to the maximum desired. It shall be so constructed that the specimens and the thermocouples can be maintained at a uniform and constant temperature at desired points within the working range. The specimen and thermocouples shall be so shielded as to prevent direct radiation from hotter, or to colder, parts of the furnace.

4.2 In order to test the uniformity of the temperature in the region to be occupied by the test specimen, a typical specimen and thermocouple shall be prepared and mounted in the center of this region. The furnace shall then be heated to its maximum temperature and maintained at this temperature until equilibrium is reached. The specimen shall then be moved in the furnace in the direction of the maximum temperature gradient through a distance equal to the maximum dimension of the largest specimen and thermocouple assembly which is to be used in this furnace. The temperature of the typical specimen in this position shall not differ from that in the normal position by more than 10°C.

5. Resistance Measurements

5.1 A Kelvin bridge, potentiometer, digital ohmmeter, or equivalent shall be used when measuring specimens having resistances less than 10 Ω. A Wheatstone bridge may be used with specimens having resistances greater than 10 Ω. The resistance of the specimen shall be measured with an accuracy

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of 0.1 %. The measuring current shall be so small that the resistance of a specimen is not changed thereby as much as 0.1 %. This condition may be determined experimentally or calculated from the power expended and the surface of the specimen.

6. Test Current

6.1 To determine experimentally that the test current is not too large, bring the specimen to a temperature (Note 1) where there is a relatively large uniform change of resistance with temperature. Apply the test current and maintain it until the resistance of the specimen has become constant. Then increase the current by 40 % and maintain it at this value until the resistance has again become constant. If the change in resistance is greater than 0.1 %, the test current is too large and shall be reduced until the foregoing limitations are reached.

NOTE 1—In the case of nickel-chromium alloy 400°C is a suitable temperature.

6.2 The test current has a negligible effect on the resistance measurement when the power lost in its passage through the specimen is less than 0.01 W/cm^2 of the effective free surface of the specimen. For straight specimens and those which are so coiled or bent that the distance between the adjacent convolutions is greater than five times the maximum transverse dimension of the cross section of the specimen, consider the free surface to be that surface area of the portion of the specimen between the potential leads. When, as for the sake of saving space in the furnace, the specimen is wound into a spiral or helix, or bent back and forth upon itself in such a manner that the distance between adjacent convolutions is less than five times the maximum transverse dimension of the cross section of the specimen, consider the free surface to be that surface area of the cylindrical or prismatic volume enclosing the coiled or convoluted specimen. Calculate the power loss due to the measuring current from the following equation:

$$W = I^2 R_m$$

where:

W = power loss, W,
I = measuring current A, and
R_m = resistance at maximum test temperature, Ω.

7. Procedure

7.1 Mount the test specimen in the furnace, bring the temperature of the furnace to the maximum specified temperature of test for the alloy in question, and hold at this value until the resistance of the specimen remains constant except for the relatively slow changes due to oxidation. Then lower the temperature of the furnace in steps of approximately 100°C to room temperature. Take measurements at each point when temperature and resistance have become stationary. Note the time at which each reading is taken. Define each point by the mean of at least one pair of resistance readings for which the current through the sample has been reversed between readings. This is necessary in order to eliminate the effects of thermal electromotive forces.

7.2 Determine the temperature by means of calibrated thermocouples, in conjunction with a potentiometer or pyrometer of such construction as to ensure an accuracy corresponding to a temperature uncertainty not exceeding 10°C.

8. Temperature-Resistance Curve

8.1 Plot a curve showing the change of resistance with temperature using the final room-temperature resistance value as a base. Note the time interval between successive readings on the curve sheet. Consider the curve thus obtained with descending temperature as defining the true temperature-resistance characteristics of the material tested.

9. Singular Points

9.1 If there are indications that the curve is not smooth at any point, carry the specimen through the temperature cycle again, and take temperature and resistance readings at intervals of approximately 25°C in the suspected region.

10. Precision and Bias

10.1 The reproducibility of the change in resistance with temperature depends primarily on the uniformity of temperature of the sample and secondarily on the rate of temperature decrease. For nickel-chromium alloys the faster the decrease in temperature, the lower the change in resistance.

10.2 The precision of this test method is within ±2 %.

10.3 The bias cannot be determined for reasons detailed in 10.1.

11. Keywords

11.1 coefficient of resistance; heating elements; resistance change; resistors; temperature-resistance