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.

Designation: A712 – 14 (Reapproved 2022)

Standard Test Method for Electrical Resistivity of Soft Magnetic Alloys[1]

This standard is issued under the fixed designation A712; 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 measurement of electrical resistivity of strip or bar specimens of soft magnetic alloys.

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

1.4 *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]

A34/A34M Practice for Sampling and Procurement Testing of Magnetic Materials

3. Summary of Test Method

3.1 The electrical resistance of a 0.25 m long (minimum) test specimen is measured with a Kelvin-type resistance bridge or a digital ohmmeter or the potentiometer-ammeter method. The resistivity is then calculated from the resistance measurement and the dimensions of the specimen and is known as the electrical resistivity of the material. This value is equal to the resistance between opposite faces of a cube of unit dimensions.

4. Significance and Use

4.1 This test method is suitable for the measurement of the electrical resistivity of specimens of soft magnetic materials.

4.2 The reproducibility and repeatability of this test method are such that it is suitable for design, specification acceptance, service evaluation, quality assurance, and research and development.

5. Apparatus

5.1 Kelvin-type resistance bridge or a digital ohmmeter (Note 1) or a dc potentiometer and dc ammeter providing resistance measurements to an accuracy within 0.5 % of the accepted true value.

NOTE 1—A digital multimeter with a four-wire resistance measuring capability can be substituted for a digital ohmmeter.

6. Sampling

6.1 Samples shall be representative of the material in the physical condition as shipped or agreed upon by the producer and the user.

7. Test Specimen

7.1 The test specimen shall be a straight strip or bar or wire of substantially uniform cross-sectional area.

7.2 It shall have a minimum length of 0.25 m.

7.2.1 Bars and wires having circular, rectangular, or other sections shall be used in the sectional dimensions as produced, unless they are so large as to require cutting a representative sample of suitable dimensions.

7.3 It shall be free of obvious surface defects.

7.4 The surface shall be cleaned by wiping with a cloth. Oil and grease, if present on the surface, shall be removed with a suitable solvent. Normal surface oxide or core plating need not be removed except in areas in which it is necessary to make satisfactory electrical contact.

8. Procedure

8.1 Measure the electrical resistance of the test specimen using a Kelvin-type resistance bridge or a digital ohmmeter or potentiometer-ammeter system having separate current and potential leads.

8.2 For strip specimens, measure the length of the test specimen to within ±0.1 % and weigh the specimen using a balance or scale capable of determining the mass within ±0.1 %. Determine the average cross-sectional area using Eq 1.

[1] This test method is under the jurisdiction of ASTM Committee A06 on Magnetic Properties and is the direct responsibility of Subcommittee A06.01 on Test Methods.

Current edition approved Oct. 1, 2022. Published October 2022. Originally approved in 1975. Last previous edition approved in 2014 as A712 – 14. DOI: 10.1520/A0712-14R22.

[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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8.3 For bar or wire specimens, determine the cross-sectional area by direct measurement using calipers or micrometers capable of measuring within ±0.1 %.

8.4 The distance between each potential lead contact and the corresponding current lead contact shall be at least twice the width of the test specimen with the two potential contacts lying between the current contacts. The distance between the potential contacts shall be not less than 0.12 m and shall be known to within ±0.1 %.

8.5 The dimension of each potential contact in the direction of the length of the specimen shall be not more than 0.5 % of the distance between potential contacts.

8.6 The contacts to the specimen shall be located centrally with respect to the specimen's width dimension, and the current contacts shall cover more than 80 % of the width. A reliable contact shall be made with the specimen by both the current and potential leads.

8.7 Specimen temperature during test shall be 25 °C ± 5 °C.

8.8 To eliminate errors as a result of contact potential, take two readings, one direct and one with the current reversed, in close succession.

8.9 The electrical current in the test specimen must be limited to avoid overheating but must be adequate to provide sufficient sensitivity to show an out-of-balance condition when the resistance reading is changed 0.5 % of the value recorded. If the current is too low, sensitivity is low also, and a balance can be shown for a broad range of resistance.

9. Calculation

9.1 *Strip Specimens:*

9.1.1 Determine the average cross-sectional area of the test specimen from the weight, length, and density as follows:

$$A = m/l\delta \tag{1}$$

where:

A = cross-sectional area of test specimen, m^2;
m = mass of test specimen, kg;
l = length of test specimen, m; and
δ = density of test specimen, kg/m^3, determined in accordance with Practice A34/A34M.

9.1.2 Eq 1 assumes a negligible mass of any coating material.

9.2 *Bar and Wire Specimens*—The cross-sectional area of the test specimen shall be based on direct measurements with a micrometer or caliper.

9.3 Calculate resistivity from the measured value of electrical resistance and the cross-sectional area as follows:

$$\rho = RA/l_2 \tag{2}$$

where:

ρ = electrical resistivity of the material, $\Omega \cdot m$;
R = resistance of electrical path, Ω;
A = cross-sectional area of electrical path, m^2; and
l_2 = length of electrical path between potential contacts on the test specimen, m.

9.4 The resistivity units in ohm-metres shown in Eq 2 can be converted to microhm-centimetres by multiplying the ohm-metre figure by 10^8 microhm-centimetres per ohm-metre. For example, if the resistivity is $0.25 \times 10^{-6}\ \Omega \cdot m$; $0.25 \times 10^{-6} \times 10^8\ \mu\Omega \cdot cm/\Omega \cdot m$ is equal to $25\ \mu\Omega \cdot cm$.

NOTE 2—The resistivities of commercial soft magnetic alloys are shown in Annex A1.

10. Precision and Bias

10.1 Although no rigorous interlaboratory comparisons of this test method have been performed, it is estimated that the reproducibility standard deviation is no greater than 2 % of the mean.

10.2 The bias of this test method is believed to be zero.

11. Keywords

11.1 electrical resistivity; magnetic alloy; potentiometer-ammeter; resistance bridge

ANNEX

(Mandatory Information)

A1. RESISTIVITIES

A1.1 This test method assumes the establishment of a uniform current density along the test specimen throughout the region between the potential contacts. The current contacts should be in the form of transverse clamps covering at least 80 % and preferably the entire width of the specimen. The potential contacts can be either knife edge or point contacts.

A1.1.1 If a potentiometer is used, a suitable dc source and ammeter are required to establish and measure the total current in the specimen, which should be limited to avoid excessive heating. The required R is then the ratio of the measured potential drop to the measured current. When the potentiometer is balanced, no current flows in the potential leads so that any contact resistance at the potential points is of no consequence.

A1.1.2 The Kelvin bridge is calibrated to read directly the resistance between the potential points without knowledge of the current in the specimen. Contact resistance at the potential