Designation: A 976 – 97

Standard Classification of Insulating Coatings by Composition, Relative Insulating Ability and Application[1]

This standard is issued under the fixed designation A 976; 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 document classifies insulating coatings according to their composition, insulating ability, and functionality. The purpose of this classification is to assist users of insulating coatings by providing general information about the chemical nature and use of the coatings, as well as to provide important data concerning limits to their use, that is, relative insulating ability, punchability, temperature stability, weldability, and fabricability. Specific surface insulation resistivity values for each coating are not included in this classification. The user is referred to the flat-rolled electrical steel specifications noted in 1.2 should more detailed information concerning surface insulation resistivity values be required.

1.2 This classification is to be used in conjunction with the various specifications for flat-rolled electrical steels under the jurisdiction of Committee A-6, including Specifications A 345, A 677, A 677M, A 683, A 683M, A 726, A 726M, A 840, A 840M, A 876, and A 876M. However, in those instances in which the coating descriptions and characteristics differ between this classification and any of the specifications, this classification shall supersede the specification.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in either customary (cgs-emu and inch-pound) units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 345 Specification for Flat-Rolled Electrical Steels for Magnetic Applications[2]

A 677 Specification for Nonoriented Electrical Steel Fully Processed Types[2]

A 677M Specification for Nonoriented Electrical Steel, Fully Processed Types (Metric)[2]

A 683 Specification for Nonoriented Electrical Steel, Semiprocessed Types[2]

A 683M Specification for Nonoriented Electrical Steel, Semiprocessed Types (Metric)[2]

A 717/A 717M Test Method for Surface Insulation Resistivity of Single Strip Specimens[2]

A 726 Specification for Cold Rolled Magnetic Lamination Quality Steel, Semiprocessed Types[2]

A 726M Specification for Cold Rolled Magnetic Lamination Quality Steel, Semiprocessed Types (Metric)[2]

A 840 Specification for Fully Processed Magnetic Lamination Steel[2]

A 840M Specification for Fully Processed Magnetic Lamination Steel (Metric)[2]

A 876 Specification for Flat Rolled, Grain Oriented, Silicon Iron, Electrical Steel, Fully Processed Types[2]

A 876M Specification for Flat Rolled, Grain Oriented, Silicon Iron, Electrical Steel, Fully Processed Types (Metric)[2]

A 937 Test Method for Determining Interlaminar Resistance of Insulating Coatings Using Two Adjacent Test Surfaces[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *interlaminar resistance, n*—the average resistance of two adjacent insulating surfaces in contact with each other, in accordance with Test Method A 937.

3.1.2 *quality anneal, n*—heat treatment used for quality control purposes and grading in accordance with the magnetic property requirements of the particular electrical steel grade. The anneal is made under conditions that ensure that the steel reaches a temperature of 1450-1550°F (790-850°C) for approximately 1 h, and with conditions that favor decarburization. The atmosphere shall contain sufficient moisture to be highly decarburizing but should not excessively oxidize the steel strips (Epstein strips for magnetic property evaluation).

[1] This classification is under the jurisdiction of ASTM Committee A-6 on Magnetic Properties and is the direct responsibility of Subcommittee A06.02 on Material Specifications.

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

An atmosphere meeting these conditions approximately 20 % hydrogen, 80 % nitrogen and has a dew point of +55°F (+ 13 °C). Care must be taken to ensure that the steel strips retain their flatness and the strip edges have ready access to the heat treatment atmosphere.

3.1.3 *stress-relief anneal, n*—heat treatment that improves the magnetic properties of electrical steel by relieving internal stresses which are introduced during fabrication of magnetic cores.

3.1.4 *surface insulation resistivity, n*—the effective resistivity of a single insulating layer tested between applied bare metal contacts and the base metal of the insulated test specimen, in accordance with Test Method A 717/A 717M.

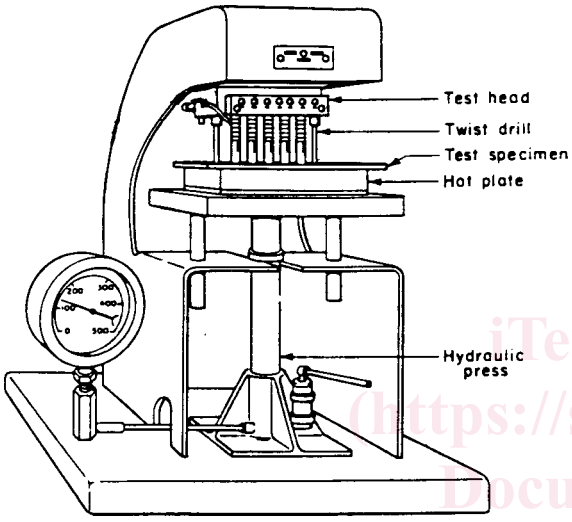

FIG. 1 Apparatus of Surface Insulation Resistivity Measurement for Franklin Test

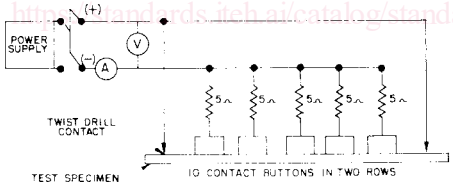

FIG. 2 Diagram of Connections for Contacts and Resistors for Franklin Test

4. Significance and Use

4.1 This classification establishes categories of insulating coatings based on their chemical nature, relative insulating ability, and typical applications. These categories describe general physical and chemical characteristics of the coatings that are useful in making broad estimates of their insulating ability and suitability for various applications.

5. Basis of Classification

5.1 The insulating coatings are categorized according to general composition, relative insulating ability, and functionality (Table 1). The purpose of this classification is to create a nomenclature for the various coating types. It is not the intent of this classification to specify coating requirements. Specific properties required by coating users should be negotiated with the steel producer.

5.2 To reduce confusion regarding the various categories of coatings, this classification follows the "C" type of designation initially used by the American Iron and Steel Institute for describing insulating coatings.[3] The "C" is included in the coating designation because insulating coatings for electrical steels have been historically referred to as "coreplate" coatings. This classification includes new coatings and test methods not included in the most recent edition of the AISI classification. Note that the electrical steel committee of the AISI is no longer active, and the 1983 edition of the coating classification document was the last edition of the coating classification to be published.[4]

6. Test Methods

6.1 The surface insulation resistivity of an insulating layer may be measured using Test Methods A 717/A 717M. In this test method, ten metallic contacts of fixed area are applied to one of the surfaces of the test specimen, and electrical contact is made with the base metal by two drills (Fig. 1 and Fig. 2). The effectiveness of the coating (surface insulation) then is indicated by a measurement of the average electrical current flowing between the contacts and the base metal under specified applied voltage. This current value often is referred to as the "Franklin Current" and may be used directly as an indicator of the quality of the insulation. Specifically, a Franklin Current of zero corresponds to a perfect insulator. A Franklin Current of 1 ampere corresponds to a perfect conductor. If desired, an apparent surface insulation resistivity value for the insulating layer may be calculated as follows:

$$R_i = 6.45\ \{(1/I) - 1\}\ \text{in}\ \Omega\cdot\text{cm}^2/\text{lamination} \quad (1)$$

or

$$R_i = 6.45\ \{(1/I) - 1\}/\ \text{in}\ [\Omega\cdot\text{mm}^2/\text{lamination}] \quad (2)$$

where:

R_i = surface insulation resistivity of test sample (two surfaces in series) in $\Omega\cdot\text{cm}^2$/lamination or $[\Omega\cdot\text{mm}^2$/lamination] and

I = ammeter reading (also known as Franklin Current).

Note that this test method often is referred to as the Franklin test. The Franklin test is a widely used method for evaluating the effectiveness of surface insulation on electrical steels.

6.2 The average resistance of two adjacent insulating surfaces in contact with each other, interlaminar resistance, may be measured using Test Method A 937. Because the interlaminar resistance is influenced by coating-to-coating contact, this test method is particularly useful for providing an estimate of the interlaminar resistance in a stacked or wound core in which coated surfaces are in contact with each other. Furthermore, this test method is particularly useful for electrical steels coated with insulating coatings having surface insulation resistivities in excess of 300 $\Omega\cdot\text{cm}^2$ [30 $\text{k}\Omega\cdot\text{mm}^2$] (that is, less than 0.02 A

[3] *Steel Products Manual on Flat–Rolled Electrical Steel*, American Iron and Steel Institute, 1101 17th St., N.W., Washington, DC 20036–4700, January 1983.

[4] Loudermilk, D. S. and Murphy, R. A., "Overview of Technology of Insulating Coatings for Grain–Oriented and Nonoriented Electrical Steels," Fifteenth Annual Conference on Properties and Applications of Magnetic Materials, Illinois Institute of Technology, Chicago, IL, May 1996.