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Standard Specification for Thin-Gauge Nonoriented Electrical Steel Fully Processed Types[1]

This standard is issued under the fixed designation A1086; 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 specification covers the detailed requirements to which flat-rolled thin-gauge nonoriented fully processed electrical steel shall conform. Nominal thicknesses included in this specification are 0.004 in. (0.10 mm) to 0.012 in. (0.30 mm).

1.1.1 Refer to Specification A677 for properties of flat-rolled nonoriented fully processed electrical steel in nominal thicknesses of 0.014 in. (0.36 mm) to 0.025 in. (0.64 mm).

1.1.2 Refer to Specification A876 for properties of flat-rolled grain-oriented fully processed electrical steel.

1.1.3 Thin-gauge nonoriented electrical steels with a high silicon content (typically 6½ %) manufactured using silicon vapor-deposition or similar processes are not included in this specification.

1.2 The steel covered in this specification is produced to specified maximum core loss values and is intended primarily for use in rotating electrical machinery and other electromagnetic devices operating at moderate to elevated frequencies (100 Hz and greater). Desirable core loss and permeability characteristics are developed during mill processing; however, lamination manufacturing processes may adversely affect these mill-produced properties. Additional stress-relief heat treatment by the user may therefore be helpful in remediating these properties in the manufactured laminations. Stress-relief annealing is discussed further in Appendix X2.

1.3 These thin-gauge nonoriented fully processed electrical steels are low-carbon, silicon-iron, or silicon-aluminum-iron alloys typically containing 2.5 to 3.5 % silicon and a small amount of aluminum.

1.4 The values stated in customary (cgs-emu and inch-pound) units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units which are provided for information only and are not considered standard.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

A340 Terminology of Symbols and Definitions Relating to Magnetic Testing

A343/A343M Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame

A348/A348M Test Method for Alternating Current Magnetic Properties of Materials Using the Wattmeter-Ammeter-Voltmeter Method, 100 to 10 000 Hz and 25-cm Epstein Frame

A664 Practice for Identification of Standard Electrical Steel Grades in ASTM Specifications

A677 Specification for Nonoriented Electrical Steel Fully Processed Types

A700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A717/A717M Test Method for Surface Insulation Resistivity of Single-Strip Specimens

A719/A719M Test Method for Lamination Factor of Magnetic Materials

A876 Specification for Flat-Rolled, Grain-Oriented, Silicon-Iron, Electrical Steel, Fully Processed Types

A927/A927M Test Method for Alternating-Current Magnetic Properties of Toroidal Core Specimens Using the Voltmeter-Ammeter-Wattmeter Method

A937/A937M Test Method for Determining Interlaminar Resistance of Insulating Coatings Using Two Adjacent Test Surfaces

A971/A971M Test Method for Measuring Edge Taper and Crown of Flat-Rolled Electrical Steel Coils

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

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[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.

A976 Classification of Insulating Coatings for Electrical Steels by Composition, Relative Insulating Ability and Application
E18 Test Methods for Rockwell Hardness of Metallic Materials
E384 Test Method for Knoop and Vickers Hardness of Materials

3. Terminology

3.1 *Definitions*—See Terminology A340.

4. Classification

4.1 The thin-gauge nonoriented electrical steel types described by this specification are as shown in Table 1.

5. Ordering Information

5.1 Orders for material under this specification shall include as much of the following information as necessary to describe the desired material adequately:

5.1.1 ASTM specification number.

5.1.2 Core-loss type designation.

5.1.3 Surface coating type.

5.1.4 Thickness, width, and length (if in cut lengths instead of coils).

5.1.5 Total weight of ordered item.

5.1.6 Limitations in coil size or lift weights.

5.1.7 *End Use*—The user shall disclose as much pertinent information as possible about the intended application to enable the producer to provide material characteristics most suitable for specific fabricating practices.

5.1.8 Special requirements or exceptions to the provisions of this specification shall be negotiated between the user and the producer.

6. Manufacture

6.1 *Typical Melting and Casting:*

6.1.1 These thin-gauge fully processed nonoriented electrical steels may be made by basic-oxygen, electric-furnace, or other steel making practices.

TABLE 1 Core-Loss Types[A] and Maximum Specific Core Losses[B] at a Magnetic Flux Density of 10 kG (1.0 T) for As-Sheared Epstein Specimens[C]

Thickness in. (mm)	Core-Loss Type	Maximum Core Loss at 400 Hz W/lb (W/kg)	Maximum Core Loss at 1000 Hz W/lb (W/kg)
0.004 (0.10)	10T590	5.90 (13.0)	12.0 (26.4)
0.005 (0.12)	12T610	6.10 (13.5)	15.3 (33.7)
0.006 (0.15)	15T640	6.40 (14.0)	17.4 (38.3)
0.007 (0.18)	18T650	6.50 (14.4)	19.5 (43.0)
0.008 (0.20)	20T680	6.80 (15.0)	22.4 (49.4)
0.009 (0.22)	22T700	7.00 (15.4)	25.0 (55.1)
0.010 (0.25)	25T730	7.30 (16.0)	28.0 (61.7)
0.011 (0.27)	27T770	7.70 (17.0)	30.2 (66.6)
0.012 (0.30)	30T820	8.20 (18.0)	32.8 (72.3)

[A] See Practice A664

[B] The test density shall be the correct ASTM assumed density (in accordance with 13.2) for the chemistry used by the producer to meet the property requirements of the specification.

[C] One half of strips cut parallel to the steel rolling direction, one half of strips cut perpendicular to the steel rolling direction. Refer to Section 13 for applicable test methods.

6.1.2 These thin-gauge fully processed nonoriented electrical steels are characterized by low carbon content, usually less than 0.02 %. The principal alloying element is commonly silicon, but aluminum up to about 0.8 % is sometimes used instead of or in addition to silicon, depending on mill-processing practice for the desired magnetic grade. Individual producers will often have different silicon or aluminum contents for a particular grade because of intrinsic mill processing procedures.

6.1.3 Additional alloying elements that may be present depending on mill processing procedures include sulfur, typically less than 0.025 %, manganese in amounts between 0.10 and 0.40 %, and phosphorus, copper, nickel, chromium, molybdenum, antimony, and tin in residual amounts.

6.1.4 The producer is not required to report the chemical composition of each lot except when a clear need for such information has been shown. In such cases, the information to be reported shall be negotiated between the producer and the user.

6.2 *Typical Rolling and Annealing*—The processing sequence for thin-gauge fully processed, nonoriented electrical steel comprises hot-rolling, annealing, pickling, cold-rolling, and decarburizing annealing.

6.2.1 *Commercial Rerolling*—When commercial practice calls for the cold-rolling to finished thickness and the development of the final annealed and coated condition to take place at a production facility other than the original melting and hot-rolling mill, this rerolling facility should prepare final test data and certifications as well as package and ship the finished material to the user in accordance with the requirements for producers stated in this standard.

6.3 When changes in the manufacture of the material are believed to exert possible significant effects upon the user's fabricating practices and upon the magnetic performance to be obtained in the specified end use, the producer shall notify the user before shipment is made so the user has an opportunity to evaluate the effects.

7. Magnetic Properties

7.1 *Specific Core Loss*—Each core-loss type of electrical steel is identified by the maximum core loss requirements as shown in Table 1.

7.2 *Permeability*—The permeability at all magnetic flux density levels shall be as high as possible, consistent with the required core loss limits that govern the grade. Typical relative peak permeability (μ_p) values are given in Appendix X1.

7.3 *Minimum Magnetic Flux Density*—The minimum magnetic flux density of materials at specified magnetic field strengths is frequently useful to the user. Typical values of minimum magnetic flux density are given in Appendix X1.

7.4 *Magnetic Aging*—Although steel sold to this specification is considered non-aging, the maximum core loss values of Table 1 are based on tests of freshly sheared specimens. The guarantee of magnetic properties after an aging treatment is subject to negotiation between the user and the producer. The definition of aging coefficient and the aging treatments usually specified are given in Terminology A340.

8. Surface Insulation Characteristics

8.1 Unless otherwise specified, thin-gauge fully processed nonoriented electrical steels are supplied with a smooth surface finish and a thin, tightly adherent surface oxide (coating type C-0 in Classification A976) which has sufficient insulating ability for many small cores.

8.2 *Applied Coatings:*

8.2.1 Several types of thin, tightly adherent applied coatings with higher levels of insulating ability, including coating type C-5 in Classification A976 as well as other standard and proprietary coating types are available on thin-gauge fully processed nonoriented electrical steels. If an applied coating is needed, the user shall specify the coating type.

8.2.2 If the insulating ability of the applied coating is unusually critical to the application, the user shall specify not only the coating type, but also the test method (either Test Method A717/A717M or Test Method A937/A937M) and test conditions to be used to evaluate the insulating ability of the coating as well as the corresponding minimum value of insulating ability.

8.2.3 A thinner than usual applied coating may be preferred when the core fabricating practice involves welding or die casting. In such cases the coating type and characteristics shall be determined by agreement of the user and producer.

9. Mechanical Requirements

9.1 *Lamination Factor*—The lamination factor shall be as high as practicable. It is greatest for thicker gages and when the surface is smooth, uncoated and without significant amounts of oxide. Lamination factors can be determined using Test Method A719/A719M. Typical values of lamination factor are given in Appendix X1.

9.2 *Hardness*—The hardness of these materials can be determined using Test Methods E18 or Test Method E384. Hardness is affected by chemistry and by the grain size and microstructure of the final product and may differ between producers. If tests for hardness are to be included with a production order, the test method or methods to be used and acceptable hardness values shall be negotiated between the user and the producer.

10. Dimensions and Permissible Variations

10.1 *Thickness*—Nominal thicknesses of each core-loss type are shown in Table 2.

10.2 *Thickness Variations*—The average thickness of the material supplied shall be as close as possible to the ordered thickness. Measurements made with a contacting micrometer at points no closer than 0.375 in. (0.95 mm) from the edge of a sheet or coil of specified width shall not differ from the specified thickness by more than the values (which include taper) shown in Table 2.

10.3 *Taper*—The rolling of flat-rolled sheets inherently produces an edge which is thinner than the rest of the sheet. This characteristic is termed "tapered edge," "feather," or gamma and occurs primarily within 1 to 2 in. (25 to 51 mm) from the as-rolled edge of the material. The thickness variation involved in edge taper sometimes is the major portion of the total overall thickness variation permitted by 10.2. Edge taper is defined and may be measured in accordance with Test Method A971/A971M; allowable taper as measured along a straight line perpendicular to the mill edge within the first 2 in. (51 mm) or less from either edge of the ordered width is presented in Table 3. It may be expected that the following limits on the differences in thickness measured will apply.

TABLE 2 Thickness Tolerances

Core-Loss Type	Nominal Thickness in. (mm)	Thickness Tolerance in. (mm)
10T590	0.004 (0.10)	± 0.0003 (0.008)
12T610	0.005 (0.12)	± 0.0004 (0.010)
15T640	0.006 (0.15)	± 0.0005 (0.013)
18T650	0.007 (0.18)	± 0.0005 (0.013)
20T680	0.008 (0.20)	± 0.0006 (0.015)
22T700	0.009 (0.22)	± 0.0007 (0.018)
25T730	0.010 (0.25)	± 0.0008 (0.020)
27T770	0.011 (0.27)	± 0.0009 (0.023)
30T820	0.012 (0.30)	± 0.0012 (0.030)

TABLE 3 Maximum Taper

Core-Loss Type	Nominal Thickness in. (mm)	Maximum Taper in. (mm)
10T590	0.004 (0.10)	0.0003 (0.008)
12T610	0.005 (0.12)	0.0003 (0.008)
15T640	0.006 (0.15)	0.0004 (0.010)
18T650	0.007 (0.18)	0.0005 (0.013)
20T680	0.008 (0.20)	0.0005 (0.013)
22T700	0.009 (0.22)	0.0006 (0.015)
25T730	0.010 (0.25)	0.0007 (0.018)
27T770	0.011 (0.27)	0.0007 (0.018)
30T820	0.012 (0.30)	0.0008 (0.02)

10.4 *Width Tolerances*—Maximum deviations from the ordered width shall be as shown in Table 4. Allowable deviations for widths >40 in. (1.0 m) shall be negotiated between the producer and the user.

10.5 *Length Tolerances*—The maximum deviations from the ordered length shall be as shown in Table 5. Allowable deviations for lengths >120 in. (3.1 m) shall be negotiated between the producer and the user.

10.6 *Camber*—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge. It is limited to 0.25 in. (6.4 mm) per 96 in. (2.4 m) of length.

10.7 *Out of Square*—This tolerance applies to cut lengths only and represents the deviation of an edge from a straight line placed at a right angle to the side, touching one corner and extending to the other side. It shall not exceed 0.063 in. (1.6 mm) per 6 in. (152 mm) of width or fraction thereof.

11. Workmanship, Finish, and Appearance

11.1 *Flatness*—Adequately defining the degree of flatness necessary for the general application of fully processed electrical steel sheets is extremely difficult; therefore, no specific limits for flatness have been established.

TABLE 4 Width Tolerances

Ordered Width, in. (m)	Width Tolerance, in. (mm)	
Under 6 (0.15), incl	+ 0.008 (0.20)	- 0.008 (0.20)
Over 6 (0.15) to 10 (0.25), incl	+ 0.016 (0.41)	- 0.016 (0.41)
Over 10 (0.25) to 16 (0.41), incl	+ 0.032 (0.81)	- 0.032 (0.81)
Over 16 (0.41) to 40 (1.0), incl	+ 0.064 (1.6)	- 0.064 (1.6)