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Standard Specification for Nonoriented Electrical Steel, Semiprocessed Types[1]

This standard is issued under the fixed designation A683; 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, nonoriented semiprocessed electrical steel shall conform.

1.2 This steel is produced to specified maximum core-loss values and is intended primarily for commercial power frequency (50 and 60 Hz) applications in magnetic devices. Desirable core-loss and permeability characteristics are developed through heat treatment by the user.

1.3 These nonoriented, semiprocessed electrical steels are low carbon, silicon-iron or silicon-aluminum-iron alloys containing up to about 2.5 % silicon and less than 1 % aluminum.

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

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

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

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

A719/A719M Test Method for Lamination Factor of Magnetic Materials

A720/A720M Test Method for Ductility of Nonoriented Electrical Steel

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

A976 Classification of Insulating Coatings for Electrical Steels by Composition, Relative Insulating Ability and Application

3. Terminology

3.1 The terms and symbols used in this specification are defined in Terminology A340.

4. Classification

4.1 The nonoriented electrical steel types described by this specification are 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 number.

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.

6. Materials and Manufacture

6.1 *Typical Melting and Casting:*

6.1.1 These semiprocessed electrical steels may be made by basic-oxygen, electric furnace, or other steelmaking practice(s).

6.1.2 These electrical steels are characterized by low carbon, usually less than 0.030 %. 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

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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.

TABLE 1 Core-Loss Types[A] and Maximum Core Losses[B] at a Magnetic Flux Density of 1.5 T (15 kG) and 60 Hz[C] of Quality Evaluation Annealed Epstein Specimens[D]

0.47 mm (0.0185 in.) Thickness			0.64 mm (0.025 in.) Thickness		
Core-Loss Type	Maximum Core Loss		Core-Loss Type	Maximum Core Loss	
	W/kg	(W/lb)		W/kg	(W/lb)
47S155	3.42	(1.55)	64S200	4.41	(2.00)
47S165	3.64	(1.65)	64S210	4.63	(2.10)
47S175	3.86	(1.75)	64S220	4.85	(2.20)
47S190	4.19	(1.90)	64S230	5.07	(2.30)

[A] See Practice A664.
[B] The test density shall be the correct ASTM assumed density (in accordance with 14.2) for the chemistry used by the producer to meet the property requirements of this specification.
[C] Maximum core losses at a magnetic flux density of 1.5 T (15 kG) and 50 Hz are 0.79 times maximum core losses at 60 Hz.
[D] One half of strips cut parallel to the steel rolling direction and one half of strips cut perpendicular to the steel rolling direction.

grade. Individual producers will often have different silicon or aluminum contents for a particular grade as a result of intrinsic mill processing procedures.

6.1.3 Sulfur content is typically less than 0.025 % and is usually lowest in the numbered types representing lowest core loss. Manganese is typically present in amounts between 0.10 and 0.70 %. Phosphorus, copper, nickel, chromium, molybdenum, antimony, and tin are usually present only in residual amounts except in the higher numbered core-loss types where phosphorus, tin, or antimony up to 0.15 % may be present.

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

6.2 *Typical Processing*—The processing sequence for semiprocessed nonoriented electrical steel comprises hot rolling, pickling, cold rolling, and annealing. An additional annealing operation may precede or follow the pickling operation.

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 maximum core-loss limits as shown in Table 1.

7.2 *Permeability*—The permeability at all magnetic flux density values 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 *Specific Exciting Power*—The knowledge of the approximate value of rms exciting power required for the excitation of a particular type of electrical steel is frequently useful to the user. Typical values of specific exciting power are given in Appendix X1.

8. Surface Insulation Characteristics

8.1 Unless otherwise specified, semiprocessed electrical steels are supplied with a thin, tightly adherent surface oxide (coating Type C-0 in Classification A976) which has sufficient insulating ability for most small cores. The insulating ability of coating Type C-0 can be enhanced during the user's heat treatment by using a slightly oxidizing atmosphere.

8.2 *Applied Coatings:*

8.2.1 Semiprocessed electrical steels may also be supplied with a thin applied coating (coating Types C-4–A and C-5–A in Classification A976) which has sufficient insulating ability for most small cores. A major purpose for using coating Types C-4–A and C-5–A is to reduce surface-to-surface sticking during the user's heat treatment.

8.2.2 When essential, higher levels of insulating ability may be obtained by coating semiprocessed electrical steels with thicker applied coatings (coating Types C-4 and C-5 in Classification A976). Usage of such coatings should be approached with great caution since the coatings may have an inhibiting effect on decarburization and thereby limit the attainment of the lowest core losses in the user's heat treatment.

9. Mechanical and Physical Properties

9.1 *Lamination Factor*—The lamination factor shall be determined using Test Method A719/A719M and shall be as high as practicable. It is normally greater for 0.64 mm (0.025 in.) thick steel than for 0.47 mm (0.0185 in.) thick steel and when the surfaces are smooth and have no applied coating.

9.2 *Ductility*—The material shall be as ductile as possible, consistent with meeting magnetic requirements. When required the ductility shall be determined by the bend test for ductility described in Test Method A720/A720M. Ductility is a function of microstructure and may differ between producers. The user's anneal may also affect ductility.

10. Dimensions and Permissible Variations

10.1 *Thickness*—Specified thickness should be one of the common thicknesses as follows:

Thickness, mm (in.)
0.64 (0.025)
0.47 (0.0185)

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 10 mm (0.375 in.) 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 *Edge Taper*—The rolling of flat-rolled strip inherently produces an edge that is thinner than the rest of the strip. This characteristic is termed "edge taper," "feather," or "gamma." Edge taper thickness variation is sometimes 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. Since edge taper occurs primarily within the first 25 or 50 mm (1 or 2 in.) from the as-rolled edge, edge slit

TABLE 2 Thickness Tolerances[A]

Specified Thickness, mm (in.)	Thickness Tolerances, Over or Under, mm (in.) for Specified Width, mm (in.)			
	152 (6) Wide and Under	Over 152 (6) to 305 (12) Wide, Incl	Over 305 (12) to 914 (36) Wide, Incl	Over 914 (36) to 1219 (48) Wide, Incl
0.47 (0.0185)	0.038 (0.0015)	0.051 (0.002)	0.051 (0.002)	0.076 (0.003)
0.64 (0.025)	0.051 (0.002)	0.051 (0.002)	0.076 (0.003)	0.076 (0.003)

[A] Thickness is measured at any point across the width not less than 10 mm (0.375 in.) from a side edge.

coils tend to have the greatest variation in thickness. The following limits on the differences in thickness measured within the first 50 mm (2 in.) or less from either edge of the ordered width will apply.

Ordered Thickness		Maximum Taper	
mm	(in.)	mm	(in.)
0.47	(0.0185)	0.031	(0.0012)
0.64	(0.025)	0.036	(0.0014)

10.4 *Width Tolerances*—Maximum deviations from the ordered width shall be as shown in Table 3.

TABLE 3 Width Tolerances

Specified Width		Width Tolerance			
		Over		Under	
mm	in.	mm	in.	mm	in.
50 to 150 incl	2 to 6, incl	0.20	(0.008)	0.20	(0.008)
over 150 to 230, incl	Over 6 to 9, incl	0.41	(0.016)	0.41	(0.016)
over 230 to 300, incl	Over 9 to 12, incl	0.81	(0.032)	0.81	(0.032)
over 300 to 760, incl	Over 12 to 30, incl	3.2	(0.125)	0	0
over 760 to 1220, incl	Over 30 to 48, incl	4.8	(0.188)	0	0
over 1220 to 1520, incl	Over 48 to 60, incl	6.4	(0.25)	0	0

10.5 *Length Tolerances*—The maximum deviations from the ordered length shall be as shown in Table 4.

TABLE 4 Length Tolerances

Specified Length		Length Tolerance			
		Over		Under	
mm	(in.)	mm	(in.)	mm	(in.)
To 760, incl	(To 30, incl)	3.2	(0.125)	0	(0)
Over 760 to 1520, incl	(Over 30 to 60, incl)	6.4	(0.25)	0	(0)
Over 1520 to 2340, incl	(Over 60 to 96, incl)	12.7	(0.50)	0	(0)
Over 2340 to 3050, incl	(Over 96 to 120, incl)	19.1	(0.75)	0	(0)
Over 3050 to 3660, incl	(Over 120 to 144, incl)	25.4	(1.00)	0	(0)

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 6.4 mm (0.25 in.) in any 2.4 m (8 ft) 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 1.6 mm (0.062 in.) in any 150 mm (6 in.) of width or fraction thereof.

11. Workmanship and Finish

11.1 *Surface Finishes*—Many applications of these steels require some treatment of the normally smooth surface to minimize sticking during the lamination anneal. This may take the form of an intentionally roughened surface or a chemical treatment of the surface commonly referred to as antistick. The several ranges of roughness that are usually available include the following as determined by a profilometer and expressed as arithmetic average micrometers at 0.76 mm (0.030 in.) cutoff and 7.6 mm/s (0.3 in./s) tracing speed:

Surface Finish	Profilometer (Ra), µm (µin.)
Smooth	0–0.5 (0–20)
Matte	0.8–1.5 (30–60)
Rough	1.8–2.8 (70–110)

The user shall specify on the order what surface finish or surface treatment is required.

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

11.2.1 It is intended that flatness shall be suitable for the intended application, and consequently the user should inform the producer of any requirements for a degree of flatness, which exceeds that obtained from usual commercial practices.

11.2.2 Commercial practices recognize that sharp, short waves and buckles are objectionable.

11.2.3 Procedures for judging the degree of critical flatness necessary shall be subject to negotiation between user and producer.

11.3 *Surface Imperfections*—The surface shall be reasonably clean and essentially free of manufacturing defects such as holes, blisters, slivers, indentations, and so forth, which would interfere with its effective use in the intended application.

12. Sampling

12.1 The producer shall assign a number to each test lot for identification. The test lot shall not exceed 9100 kg (20 000 lb) in weight.

12.2 Test samples shall be obtained after final mill heat treatment or other operation which is the final operation to have significant influence on the magnetic properties of semiprocessed electrical steel.

12.3 The full width coil identified as a test lot shall be sampled in accordance with Practice A34/A34M.

13. Specimen Preparation

13.1 The Epstein test specimen shall consist of one half of the test strips obtained parallel to rolling and one half transverse to the rolling direction, in accordance with Fig. 1 of Practice A34/A34M.

13.2 To determine conformity with the magnetic requirements of this specification, the specimen strips to be tested

shall be given a controlled quality evaluation anneal in a decarburizing atmosphere. The anneal shall be made under conditions which ensure that the specimen strips reach a temperature of 843°C (1550°F) except that the temperature shall be 788°C (1450°F) for alloy contents less than 1.3 % silicon plus aluminum, for approximately 1 h and with conditions favorable to decarburization. The atmosphere shall contain sufficient moisture to be highly decarburizing but should not excessively oxidize the specimens. An atmosphere meeting these conditions contains about 20 % hydrogen, 80 % nitrogen and has a dew point of +13°C (+55°F). Care shall be taken to maintain the strips flat in the anneal and to permit ready access of the atmosphere to the edges of the specimen strips.

13.3 Care shall be practiced to exclude from the test specimen any bent, twisted, heavily burred, or improperly sheared strips.

14. Test Methods

14.1 The required tests for core loss to determine the core-loss grade, and other magnetic tests when made, shall be in accordance with the procedure of Test Method A343/A343M.

14.2 The assumed density of these materials for test purposes varies according to the amounts of silicon and aluminum present in the steel as shown in Practice A34/A34M. The factor, percent silicon plus 1.7 multiplied by percent aluminum as determined for the median or aim silicon and aluminum of the melt, shall determine the assumed density to be used as follows:

Chemical Composition (% Si + 1.7 × % Al)	Assumed Test Density, kg/m^3 (g/cm^3)
0.00–0.62	7850 (7.85)
0.63–1.38	7800 (7.80)
1.39–2.15	7750 (7.75)
2.16–2.92	7700 (7.70)
2.93–3.69	7650 (7.65)
3.70–4.46	7600 (7.60)

15. Certification

15.1 The producer shall submit to the user, as promptly as possible after shipment, a certified report of the average core-loss values or any other required test values, for each test lot, to show that the material conforms to this specification.

15.2 The test methods and applicable test conditions, including the test density, shall be clearly stated.

15.3 The test report shall carry the lot identification, purchase order number, and other information that is deemed necessary to identify the test results with the proper shipment and shipping lot.

16. Marking

16.1 Each package of coils or lift of cut lengths shall have firmly attached to its outside wrappings, a tag showing the user's order number, specification number, grade designation, coating or surface type-designation, thickness, width, (and length if in sheet form), weight, and test lot number.

16.2 Each wide coil shall have the specification number, grade designation, coating or surface-type designation, thickness, width, weight, and test lot number marked on the outer surface of the coil itself.

16.3 In a lift of narrow coils, each narrow coil in the package shall be tagged with the specification number, grade designation, coating or surface-type designation, thickness, width, and test lot number.

17. Packaging

17.1 Methods of packaging, loading, and shipping, unless otherwise specified, shall correspond to the latest revision of the procedures recommended by Practices A700.

18. Rejection

18.1 Unless otherwise specified, any rejection shall be reported to the producer within reasonable time after receipt of material by the user.

18.2 Material that is reported to be defective subsequent to the acceptance at the user's works shall be set aside, adequately protected, and correctly identified. The producer shall be notified as soon as possible so that an investigation may be initiated.

18.3 Samples that are representative of the rejected material shall be made available to the producer so a mutually agreeable settlement can be reached.

19. Keywords

19.1 core loss; electrical steel; flat-rolled; nonoriented; semiprocessed

APPENDIX

(Nonmandatory Information)

X1. TYPICAL PROPERTIES

X1.1 *Peak Permeability*—Typical values for relative peak permeability (μ_p) at a magnetic flux density of 1.5 T (15 kG) determined in accordance with Test Method A343/A343M are given in Table X1.1.

X1.2 *Specific Exciting Power*—Typical values of specific exciting power for these materials at 1.5 T (15 kG) and 60 Hz determined in accordance with Test Method A343/A343M are provided in Table X1.2.

TABLE X1.1 Typical Values for Relative Peak Permeability at 1.5 T (15 kG) and 60 Hz of Quality Evaluation Annealed Epstein Specimens[A]

0.47 mm (0.0185 in.) Thickness		0.64 mm (0.025 in.) Thickness	
Core-Loss Type	Typical Relative Peak Permeability	Core-Loss Type	Typical Relative Peak Permeability
47S155	1700–2500	64S200	2000–2900
47S165	2000–2900	64S210	2400–3400
47S175	2100–3000	64S220	2400–3400
47S190	2100–3000	64S230	2400–3400

[A] One half of strips cut parallel to the steel rolling direction and one half of strips cut perpendicular to the steel rolling direction.

TABLE X1.2 Typical Values for Specific Exciting Power at 1.5 T (15 kG) and 60 Hz of Quality Evaluation Annealed Epstein Specimens[A]

0.47 mm (0.0185 in.) Thickness		0.64 mm (0.025 in.) Thickness	
Core-Loss Type	Typical Specific Exciting Power, VA/kg (VA/lb)	Core-Loss Type	Typical Specific Exciting Power, VA/kg (VA/lb)
47S155	8.8–12.1 (4.0–5.5)	64S200	8.8–11.0 (4.0–5.0)
47S165	7.7–11.0 (3.5–5.0)	64S210	7.7–9.9 (3.5–4.5)
47S175	7.7–11.0 (3.5–5.0)	64S220	7.7–9.9 (3.5–4.5)
47S190	7.7–11.0 (3.5–5.0)	64S230	7.7–9.9 (3.5–4.5)

[A] One half of strips cut parallel to the steel rolling direction and one half of strips cut perpendicular to the steel rolling direction.