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

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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-~~(50 and ~~60-Hz)~~ 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 ~~customary (cgs-emu and inch-pound)~~ SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to ~~SI~~ 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.

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[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.

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

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

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 ~~15 kG (1.5 T)~~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.

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 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 ~~Property Requirements~~ 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 ~~inductions~~ 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-AS~~C-4–A and ~~C-5-AS~~C-5–A in Classification A976) which has sufficient insulating ability for most small cores. A major purpose for using coating Types ~~C-4-AS~~C-4–A and ~~C-5-AS~~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 ~~Requirements~~ 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 ~~0.025-in. (0.64-mm)~~ 0.64 mm (0.025 in.) thick steel than for ~~0.0185-in. (0.47-mm)~~ 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, ~~in. (mm)~~mm (in.)
~~0.025 (0.64)~~0.64 (0.025)
~~0.0185 (0.47)~~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 ~~⅜ in. (10 mm)~~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

TABLE 2 Thickness Tolerances[A]

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

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 ~~⅜ in. (10 mm)~~10 mm (0.375 in.) from a side edge.

A971. Since edge taper occurs primarily within the first ~~1 or 2 in. (25 or 50 mm)~~25 or 50 mm (1 or 2 in.) from the as-rolled edge, edge slit coils tend to have the greatest variation in thickness. The following limits on the differences in thickness measured within the first ~~2 in. (50 mm)~~50 mm (2 in.) or less from either edge of the ordered width will apply.

Ordered Thickness		Maximum Taper	
~~in.~~ mm	~~mm~~ (in.)	~~in.~~ mm	~~mm~~ (in.)
~~0.0185~~ 0.47	~~0.47~~ (0.0185)	~~0.0012~~ 0.031	~~0.031~~ (0.0012)
~~0.025~~ 0.64	~~0.64~~ (0.025)	~~0.0014~~ 0.036	~~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	
~~in.~~	~~mm~~	~~in.~~	~~mm~~	~~in.~~	~~mm~~
~~2 to 6, incl~~	~~(50 to 150 incl)~~	~~0.008~~	~~(0.20)~~	~~0.008~~	~~(0.20)~~
~~Over 6 to 9, incl~~	~~(over 150 to 230, incl)~~	~~0.016~~	~~(0.41)~~	~~0.016~~	~~(0.41)~~
~~Over 9 to 12, incl~~	~~(over 230 to 300, incl)~~	~~0.032~~	~~(0.81)~~	~~0.032~~	~~(0.81)~~
~~Over 12 to 30, incl~~	~~(over 300 to 760, incl)~~	~~⅛~~	~~(3.2)~~	~~0~~	~~0~~
~~Over 30 to 48, incl~~	~~(over 760 to 1220, incl)~~	~~3/16~~	~~(4.8)~~	~~0~~	~~0~~
~~Over 48 to 60, incl~~	~~(over 1220 to 1520, incl)~~	~~¼~~	~~(6.4)~~	~~0~~	~~0~~

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.

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 ~~¼ in. (6.4 mm) in any 8-ft (2.4-m)~~ 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 ~~1/16 in. (1.6 mm) in any 6 in. (150 mm)~~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 ~~microinches at 0.030-in. (0.76-mm) cutoff and 0.3-in./s (7.6-mm)~~ micrometers at 0.76 mm (0.030 in.) cutoff and 7.6 mm/s (0.3 in./s) tracing speed: