~~Designation:A876–03~~ Designation: A 876 – 09

Standard Specification for Flat-Rolled, Grain-Oriented, Silicon-Iron, Electrical Steel, Fully Processed Types[1]

This standard is issued under the fixed designation A 876; 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 the specified grades of flat-rolled, grain-oriented, fully processed electrical steels shall conform. These steels are used primarily in transformer cores operating at moderate to high magnetic flux densities at commercial power frequencies (50 and 60 Hz).

1.2 These grain-oriented electrical steels are low-carbon, silicon-iron alloys with a silicon content of approximately 3.2 % in which low core loss and high permeability in the direction of rolling have been achieved by appropriate metallurgical processing.

1.3 The electrical-steel grades described in this specification include (*1*) conventional grain-oriented electrical steel tested at 15 kG (1.5 T) in accordance with Test Method A 343/A 343M, (*2*) conventional grain-oriented electrical steel tested at 17 kG (1.7 T) in accordance with Test Method A 343/A 343M, (*3*) high-permeability grain-oriented electrical steel tested at 17 kG (1.7 T) in accordance with Test Method A 343/A 343M, and (*4*) laser-scribed high-permeability grain-oriented electrical steel tested at 17 kG (1.7 T) in accordance with Test Methods A 804/A 804M.

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.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 34/A 34M Practice for Sampling and Procurement Testing of Magnetic Materials

A 340 Terminology of Symbols and Definitions Relating to Magnetic Testing

A 343/A 343M Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame

A 345 Specification for Flat-Rolled Electrical Steels for Magnetic Applications

A 664 Practice for Identification of Standard Electrical Steel Grades in ASTM Specifications

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for ~~Domestic~~ Shipment

A 717/A 717M Test Method for Surface Insulation Resistivity of Single-Strip Specimens

A 719/A 719M Test Method for Lamination Factor of Magnetic Materials

A~~721~~ 721/A 721M Test Method for Ductility of Oriented Electrical Steel

A 804/A 804M Test Methods for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Sheet-Type Test Specimens

A 937/A 937M Test Method for Determining Interlaminar Resistance of Insulating Coatings Using Two Adjacent Test Surfaces

A 976 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 A 340.

4. Classification

4.1 The ASTM core-loss type designations, formulated in accordance with Practice A 664, for grain-oriented electrical steels covered by this specification are listed in Table 1.

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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.

This specification replaces A 665, A 725, and A 843.

Current edition approved ~~Oct.~~May 1, ~~2003.~~2009. Published ~~November 2003.~~June 2009. Originally approved in 1987. Last previous edition approved in ~~1998~~2003 as ~~A876/A876M–98.~~A 876–03.

[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 Type Designations

Conventional Grain-Oriented Electrical Steel
Tested at 15 kG (1.5 T) in Accordance with Test Method A 343/A 343M

ASTM Core-Loss Type[A]	Aim Thickness,[B] in. (mm)	Maximum Specific Core Loss,[C] W/lb (W/kg)	
		60 Hz	50 Hz
18G041	0.0070 (0.18)	0.41 (0.90)	0.31 (0.68)
23G045	0.0090 (0.23)	0.45 (0.99)	0.34 (0.75)
27G051	0.0106 (0.27)	0.51 (1.12)	0.39 (0.85)
30G058	0.0118 (0.30)	0.58 (1.28)	0.44 (0.97)
35G066	0.0138 (0.35)	0.66 (1.46)	0.50 (1.11)

Conventional Grain-Oriented Electrical Steel
Tested at 17 kG (1.7 T) in Accordance with Test Method A 343/A 343M

ASTM Core-Loss Type[A]	Aim Thickness,[B] in. (mm)	Maximum Specific Core Loss,[C] W/lb (W/kg)	
		60 Hz	50 Hz
23H070	0.0090 (0.23)	0.70 (1.54)	0.53 (1.17)
27H074	0.0106 (0.27)	0.74 (1.63)	0.56 (1.24)
30H083	0.0118 (0.30)	0.83 (1.83)	0.63 (1.39)
35H094	0.0138 (0.35)	0.94 (2.07)	0.71 (1.57)

High-Permeability Grain-Oriented Electrical Steel
Tested at 17 kG (1.7 T) in Accordance with Test Method A 343/A 343M

ASTM Core-Loss Type[A]	Aim Thickness,[B] in. (mm)	Maximum Specific Core Loss,[C] W/lb (W/kg)	
		60 Hz	50 Hz
23P060	0.0090 (0.23)	0.60 (1.32)	0.46 (1.01)
27P066	0.0106 (0.27)	0.66 (1.46)	0.50 (1.11)

Laser-Scribed High-Permeability Grain-Oriented Electrical Steel
Tested at 17 kG (1.7 T) in Accordance with Test Methods A 804/A 804M

ASTM Core-Loss Type[A]	Aim Thickness,[B] in. (mm)	Maximum Specific Core Loss,[D] W/lb (W/kg)	
		60 Hz	50 Hz
23Q054	0.0090 (0.23)	0.54 (1.19)	0.41 (0.90)
~~27Q057~~	~~0.0106 (0.27)~~	~~0.58 (1.28)~~	~~0.44 (0.97)~~
27Q057	0.0106 (0.27)	0.57 (1.26)	0.43 (0.96)

[A] See Practice A 664.
[B] These shall be the overall thicknesses as measured by contacting micrometre caliper.
[C] Based on parallel-grain Epstein specimens, stress-relief annealed after shearing in accordance with 14.1.2.
[D] Based on as-sheared parallel-grain sheet-type specimens. Stress-relief annealing will nullify the core-loss reduction produced by the laser scribing.

5. Condition

5.1 These grain-oriented electrical steels may be purchased in any of the following conditions (which are combinations of material form and surface type or treatment) as desired for the expected end use.

5.1.1 *Condition NF*—An annealed coil form having an inorganic surface coating, Type C-2 (Note 1). This material is not flattened and so exhibits appreciable coil curvature. The principal application is in spirally wound or formed cores in which the strip curvature is not detrimental to fabricating procedures or device performance.

5.1.2 *Condition F2*—Thermally flattened sheet or coiled strip having an inorganic surface coating, Type C-2, plus a thinner (compared to Condition F5) inorganic coating, Type C-5, applied over the inherent C-2 coating. The principal application is in spirally wound or formed cores in which strip curvature would be detrimental to fabricating procedures.

5.1.3 *Condition F5*—Thermally flattened sheet or coiled strip having an inorganic surface coating, Type C-2, plus an inorganic coating, Type C-5, applied over the inherent C-2 coating to provide extra surface insulation resistance. The principal application is in flat sheared laminations for cores of power transformers.

5.1.4 *Condition PQ*—Thermally flattened sheet or coiled strip (sometimes called "punching quality") with the inherent C-2 coating removed and an inorganic coating, Type C-5, applied for insulative purposes. The principal application is in flat stamped laminations for small stacked cores with only moderate surface insulation requirements.

NOTE 1—Additional description of surface coating Types C-2 and C-5 is presented in Specification A 345 and Classification A 976.

5.2 Core-loss types having code letters P and Q are available only in Condition F5.

6. Ordering Information

6.1 Orders for material under this specification shall include such of the following information as is required to describe the material adequately:

6.1.1 ASTM specification number,
6.1.2 ASTM core-loss type designation (Table 1),
6.1.3 Material condition (form and surface type) designation (5.1),
6.1.4 Ductility class (when required),
6.1.5 Sheet or strip width,
6.1.6 Length (only when cut lengths are specified),
6.1.7 Total weight of each ordered item,
6.1.8 Limitations on lift weight,
6.1.9 Limitations on coil size,
6.1.10 *End Use*—(Whenever practicable, the user should specify whether the ordered material will be made into flat sheared laminations, flat stamped laminations, wound cores, bonded wound cores, formed lamination cores, welded lamination cores, and so forth. This will help the producer to provide the most suitable material for the user's fabricating practices), and
6.1.11 Exception to the specification or special requirements.

7. Materials and Manufacture

7.1 Normally, these steels contain approximately 3.2 % silicon and the balance iron with residual elements at a minimum. When requested, the producer shall provide a statement of chemical composition typical of the material being supplied.

7.2 These electrical steels may be made by the basic-oxygen or electric-furnace process.

7.3 When changes in the manufacture of successive shipments of the material are believed to increase the likelihood of adverse effects upon the magnetic performance or fabrication for the specified end use, the producer shall notify the user as soon as possible before shipment is made so that he can be afforded an opportunity to evaluate the effects.

8. Magnetic Properties

8.1 *Core Loss*:

8.1.1 Maximum permissible specific core losses at 15 or 17 kG (1.5 or 1.7 T), 50 and 60 Hz, are guaranteed and are listed in Table 1 for the ASTM core-loss types. The sampling, specimen preparation, and testing practices that are described herein must be followed when conformity to these guarantees is being checked.

8.1.2 Material that conforms to both the core-loss and thickness limits of this specification shall be identified by this specification number and the appropriate core-loss designation.

8.2 *Permeability*:

8.2.1 The permeability at all magnetic flux densities shall be as high as practicable. The quality control of these grades is normally based on a measurement of relative peak permeability, μ_p, at a peak ac magnetic field strength, H_p, of 10 Oe (796 A/m). For the conventional grain-oriented grades, the value of relative μ_p at 10 Oe (796 A/m) is commonly above 1800. For the high-permeability grades, it is commonly above 1880.

8.3 *Magnetic Aging*:

Although the magnetic properties of these electrical steels are considered to be stable, the maximum core-loss values of Table 1 are based on tests of non-aged specimens. The guarantee of magnetic properties after an aging treatment is subject to negotiation between the user and the producer.

9. Surface Insulation Characteristics

9.1 The surfaces types produced in each of the material conditions of 5.1 normally have different levels of insulating ability. Interlaminar resistance of two adjacent test surfaces is determined with Test Method A 937/A 937M. Surface insulation resistivity of a single test surface is determined with Test Method A 717/A 717M. Typical ranges for surface insulation effectiveness of the various surface types are given in Appendix X1.

9.2 When insulative characteristics substantially different than those listed in Appendix X1 are necessary, the specific requirements and the procedures for evaluating them shall be negotiated between the user and the producer.

10. Physical and Mechanical Properties

10.1 *Lamination Factor*—The lamination factor shall be as high as practicable consistent with the material thickness and condition. Lamination factor may be determined using Test Method A 719/A 719M. Typical lamination factor values for the