Designation: A 876/A 876M – 98

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/A 876M; 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 inductions 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, (*2*) conventional grain-oriented electrical steel tested at 17 kG [1.7 T] in accordance with Test Method A 343, (*3*) high-permeability grain-oriented electrical steel tested at 17 kG [1.7 T] in accordance with Test Method A 343, 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 either customary (cgs-emu and inch-pound) units or SI units are to be regarded separately as standard. 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 to this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 34/A 34M Practice for Sampling and Procurement Testing of Magnetic Materials [2]

A 340 Terminology of Symbols and Definitions Relating to Magnetic Testing [2]

A 343 Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame [2]

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

A 664 Practice for Identification of Standard Electrical- and Lamination-Steel Grades in ASTM Specifications [2]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment [3]

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

A 719 Test Method for Lamination Factor of Magnetic Materials [2]

A 721 Test Method for Ductility of Oriented Electrical Steel [2]

A 804/A 804M Test Methods for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Sheet-Type Test Specimens [2]

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

A 976 Classification of Insulating Coatings by Composition, Relative Insulating Ability and Application [2]

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.

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

[1] This specification 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.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

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			
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			
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			
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]

[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.

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 deterimental 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 of lift weight,

6.1.9 Limitations on coil size requirements,

6.1.10 *End Use* (Whenever practicable, the purchaser 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 purchaser'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 purchaser 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 inductions 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 purchaser 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. 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 purchaser and the manufacturer.

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. Typical lamination factor values for the various material thickness and condition combinations are shown in Appendix X1.

10.2 *Ductility*—The ductility shall be as high as practicable. When the application requires forming around a sharp radius during fabrication, and an evaluation of the ductility is required, the ductility rating shall be determined in accordance with Test Method A 721. Ductility ratings in the following classes are appropriate for grain-oriented steels in any thickness and condition when tested at room temperature with a bend transverse to the rolling direction with "as-sheared" specimens:

Ductility Class	Permissible Number of Fractures at Bend [A]
1	none
2	1 or 2, total length not over 0.5 in. [12.7 mm]
3	3 to 8

[A] Based on 24- to 36-in. [610- to 910-mm] width of material. For widths less than 24 in. [610 mm], the number of permissible fractures should be reduced in proportion to the ratio of the width to 24 in. [610 mm].

11. Dimensions and Permissible Variations

11.1 *Thickness*—The aim thicknesses of the ASTM core-loss types are listed in Table 1.

11.1.1 *Thickness Variations*—The thickness measured at any location not less than 0.4 in. [10 mm] from an edge shall not deviate more than ±0.001 in. [±0.025 mm] from the average thickness of the test lot or coil. The outer limits of acceptable thickness of the ASTM core-loss type shall be as shown in Table 2.

11.2 *Width Tolerances*—The width of material supplied, either as coils or cut lengths, shall be as close as possible to the ordered width, but in no case shall the maximum deviations from the specified width exceed the values given in Table 3.