Designation: A726 – 18

Standard Specification for Cold-Rolled Magnetic Lamination Quality Steel, Semiprocessed Types[1]

This standard is issued under the fixed designation A726; 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 cold-rolled carbon sheet steel used for magnetic applications. These products, commonly called "cold-rolled magnetic lamination steel" (CRML) are usually intended for applications in which the stamped laminations or assembled core structures for electrical equipment are annealed to develop the desired core loss and permeability characteristics.

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

1.3 Non-guaranteed core-loss types, usually made to controlled chemical compositions, are available but are not covered by this specification.

1.4 Higher quality core-loss types are low carbon, silicon-iron, or silicon-aluminum-iron alloys containing up to about 2.5 % silicon and less than 1 % aluminum. These steels are usually given a critical reduction on a temper-mill to yield specified magnetic properties after a suitable lamination anneal. These products, typically called semiprocessed magnetic lamination steel, are classified by the ASTM Code Letter D in accordance with Practice A664.

1.5 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.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

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

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

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

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

E18 Test Methods for Rockwell Hardness of Metallic Materials

E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

[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.

Current edition approved Oct. 1, 2018. Published October 2018. Originally approved in 1976. Last previous edition approved in 2010 as A726 – 05 (2010). DOI: 10.1520/A0726-18.

[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.

3. Terminology

3.1 *Definitions*—See Terminology A340.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cold-rolled sheet*—sheet manufactured from hot-rolled descaled coils by cold reducing to the desired thickness, generally followed by annealing to recrystallize the grain structure. In the case of magnetic lamination steels, particularly semiprocessed lamination steels, temper rolling is used after annealing to enhance flatness and optimize magnetic properties during the user's lamination anneal.

3.2.2 *magnetic lamination steels*—specialty cold-rolled carbon sheet steel melted to controlled levels of carbon with additions of manganese, phosphorus, silicon, and aluminum. Residual elements are generally held as low as possible. The appropriate chemical composition combined with controlled mill processing results in a carbon sheet steel having mechanical properties and magnetic properties (after a quality development anneal) desired for electrical applications.

4. Classification

4.1 The cold-rolled magnetic lamination steel types described by this specification are shown in Table 1.

5. Ordering Information

5.1 Orders for material under this specification shall include the following information, as required, to describe the required material adequately:

5.1.1 ASTM specification number and date of issue.

5.1.2 Core-loss type number.

5.1.3 Surface texture (indicate typical profilometer range, as required) (see 11.2).

5.1.4 Specify not oiled or oiled, as required (see 11.4).

5.1.5 Dimensions (nominal thickness and coil width) and tolerances, if not standard (see 10.1).

5.1.6 Coil size (must include limitations on inside diameter and maximum weight).

5.1.7 Application (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.

5.1.9 Cast or heat analysis and magnetic test report (request if required).

NOTE 1—A typical description is as follows: Cold-Rolled Sheet, Magnetic Lamination Steel, ASTM A726 64D480, Surface Roughness 1.3- to 2.0-µm (50- to 80-µin.) arithmetic average (R_A), Not Oiled, 0.64 by 1245 mm (0.025 by 49 in.) by coil, 610-mm (24-in.) inside diameter, 9000 kg (20 000 lb) maximum, for fractional horsepower motors.

6. Materials and Manufacture

6.1 *Melting Practice*—These steels are typically made by the basic-oxygen or electric-furnace process.

6.1.1 These steels are characterized by low carbon, usually less than 0.060 %. For higher quality core-loss types, the

TABLE 1 Core-Loss Types and Maximum Specific Core-Loss Values at 1.5 T (15 Kilogauss) and 60 Hz

NOTE 1— Specific core-loss values are developed after quality development anneal (QDA) per the recommended practices in 13.3 of this specification Epstein test specimens (with one half cut parallel and the other half cut perpendicular to the direction of rolling).

NOTE 2—Maximum specific core-loss values at 50 Hz are 0.79 × maximum core-loss values at 60 Hz.

Sheet Thickness, mm (in.)	Core-Loss Type	Maximum Core Loss, W/kg	Maximum Core Loss, W/lb
0.36 (0.0140)	36D145	3.20	1.45
	36D155	3.42	1.55
0.47 (0.0185)	47D165	3.64	1.65
	47D175	3.86	1.75
	47D190	4.19	1.90
	47D215	4.74	2.15
	47D270	5.95	2.70
	47D330	7.28	3.30
	47D380	8.38	3.80
0.56 (0.022)	56D230	5.07	2.30
	56D260	5.73	2.60
	56D310	6.84	3.10
	56D380	8.38	3.80
	56D440	9.70	4.40
0.64 (0.025)	64D260	5.73	2.60
	64D290	6.40	2.90
	64D360	7.94	3.60
	64D430	9.48	4.30
	64D490	10.8	4.90
0.71 (0.028)	71D410	9.04	4.10
	71D480	10.6	4.80
	71D550	12.1	5.50
0.79 (0.031)	79D450	9.92	4.50
	79D540	11.9	5.40
	79D610	13.5	6.10

carbon content is typically less than 0.04 % and may be reduced to less than 0.02 % by means of vacuum degassing, argon stirring, or other steel refining practices when such low-carbon contents are required to facilitate decarburizing during annealing. Some magnetic lamination steels are produced to carbon contents less than 0.005 %. In these steels, decarburization during annealing may not be required. The principle 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. Manganese or phosphorus may also be added to enhance punchability and improve magnetic characteristics.

6.1.2 Residual elements found in steels are generally held as low as practical.

6.1.3 In the past, the alloy additions to magnetic lamination steels have been restricted such that the density of the steel was maintained above 7825 kg/m^3 (7.825 g/cm^3). However, higher quality core-loss type magnetic lamination steels may have alloy contents with density values less than 7825 kg/m^3 (7.825 g/cm^3) and subsequent testing for magnetic properties shall be in accordance with the procedure of Test Method A343/A343M (see Section 12).

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 Rolling and Annealing*—The processing sequence for magnetic lamination steel comprises hot rolling, pickling, cold rolling, annealing, and temper rolling. An additional annealing operation may precede or follow the pickling operation.

6.2.1 Magnetic lamination steels (all types) are cold reduced to thickness and are usually temper rolled after box or continuous annealing to enhance magnetic property development during the user's lamination anneal. In addition, the temper pass is used to improve sheet flatness and punchability and to obtain the required surface texture. Special emphasis may be placed on high extensions (2 to 10 %) during the temper roll after annealing.

6.2.2 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 that user has an opportunity to evaluate the effects.

7. Magnetic Property Requirements

7.1 The magnetic properties of these steels are optimized when the stamped laminations or assembled core structures are annealed to reduce the carbon content to 0.005 % or less. To avoid sticking of laminations and assure adequate decarburization, the annealing temperature should be in the range from 730 to 845°C (1350 to 1500°F). Time at temperature will vary with lamination dimensions, charge size, surface finish, and annealing furnace characteristics. A partially combusted natural gas atmosphere with suitable dew point is often used. Also, some users of lamination steels use a hydrogen-nitrogen gas mixture with a suitable dew point. For steel containing manganese, silicon, and aluminum, annealing conditions shall be such that subsurface oxidation of these elements is minimized.

7.2 *Specific Core Loss*—Each core loss type is identified by maximum specific core-loss limits as shown in Table 1.

7.3 *Permeability*—The permeability at all magnetic flux density levels shall be as high as possible consistent with the required maximum specific core-loss limits that govern the grade. The typical values of relative peak permeability for higher quality core-loss types are given in Appendix X1.

8. Surface Insulation Characteristics

8.1 Unless otherwise specified, cold-rolled magnetic lamination steels are supplied with no mill-applied coating. A user-formed oxide (coating Type C-1 in Classification A976) can be created at the end of the heat treating cycle and provides adequate insulation for most applications.

8.2 *Applied Coatings:*

8.2.1 Several types of thin, tightly adherent applied coatings can be applied to magnetic lamination steels. If a coating will be applied, the surface finish (see 10.2) may be altered to ensure proper insulating characteristics and coating adherence. Most suitable for magnetic lamination steels are coatings designed to withstand the heat treatment performed after stamping (coating Type C-5 in Classification A976).

8.2.2 The use of coatings as specified in Classification A976, or other coatings, as well as the test method (Test Methods A717/A717M or A937/A937M), minimum value of insulating ability and other conditions for evaluating the effectiveness of the coating, shall be determined by agreement between the user and producer. 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 specific core losses in the user's heat treatment.

9. Mechanical Properties

9.1 Hardness in the finished product depends on chemical composition and mill processing. For the mill process annealed and temper rolled condition, hardness values typically range from Rockwell 45 to 85 HRB.

9.2 Specific ranges of hardness are subject to negotiation and should be specified on the order.

9.3 Rockwell hardness measurements are normally determined by a superficial test (R30T and R15T) and converted to a B scale value in accordance with Test Methods E18 and Tables E140.

9.4 When mechanical tests are required, test specimens shall be prepared and mechanical tests conducted in accordance with Test Methods and Definitions A370.