Designation: A 726 – 05

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

This standard is issued under the fixed designation A 726; 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 By using appropriate lamination annealing practices, the user can optimize magnetic properties for the various types.

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 made to controlled chemical compositions and 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 lamination steel, are classified by the ASTM Code Letter D in accordance with Practice A 664.

1.5 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 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 370 Test Methods and Definitions for Mechanical Testing of Steel Products

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

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

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 140 Hardness Conversion Tables for Metals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *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.

3.1.2 *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.

3.2 Other terms and symbols used in this specification are defined in Terminology A 340.

4. Ordering Information

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

4.1.1 ASTM specification number and date of issue.

4.1.2 Core-loss type number.

4.1.3 Finish (indicate typical profilometer range, as required) (see 10.2).

4.1.4 Specify not oiled or oiled, as required (see 10.4).

[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.

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4.1.5 Dimensions (nominal thickness and coil width) and tolerances, if not standard (see 9.1).

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

4.1.7 Application (scroll slit for hermetic motors, and so forth).

4.1.8 Special requirements (indicate hardness range, magnetic limitations, and so forth).

4.1.9 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 A 726 64D480, Surface Roughness 50- to 80-µin. (1.3- to 2.0-µm) arithmetic average (R_A), Not Oiled, 0.025 by 49 in. (0.64 by 1245 mm) by coil, 24-in. (610-mm) inside diameter, 20 000 lb (9000 kg) maximum, for fractional horsepower motors.

5. Materials and Manufacture

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

5.2 *Typical Rolling and Annealing*—The processing sequence for magnetic lamination steel comprises hot rolling, pickling, cold rolling, annealing, and temper rolling.

5.2.1 Magnetic lamination steels (all types) are cold reduced to thickness. The non-guaranteed core-loss type product can also be sold in the as-annealed condition or after a temper mill pass to flatten and to impart the required surface texture (surface roughness). Magnetic lamination steels 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.

5.2.2 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.

6. Chemical Composition

6.1 Magnetic lamination steels have low-carbon contents. For the non-guaranteed core-loss type, the carbon content is less than 0.06 %. For higher quality core-loss types, the 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.

6.2 Magnetic lamination steels may have manganese, phosphorus, silicon, and aluminum added to enhance punchability and to improve magnetic characteristics by increasing electrical resistivity. Other elements in small controlled amounts may be used in the manufacture of these steels. In the past, the alloy additions to magnetic lamination steels have been restricted such that the density of the steel was maintained above 7.825 g/cm^3 (7825 kg/m^3). However, higher quality core-loss type magnetic lamination steels may have alloy contents with density values less than 7.825 g/cm^3 (7825 kg/m^3) and subsequent testing for magnetic properties shall be in accordance with the procedure of Test Method A 343/A 343M (see Section 12).

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

7. Magnetic Properties

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 1350 to 1500°F (730 to 845°C). 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 Core losses of higher quality core-loss types are guaranteed and shall conform to the limits given in Table 1. Relative peak permeability is a dimensionless quantity which is the same in all unit systems. The typical values of relative peak permeability for higher quality core-loss types are given in Appendix X1.

8. Mechanical Properties

8.1 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.

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

8.3 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 E 18 and Tables E 140.

8.4 When mechanical tests are required, test specimens shall be prepared and mechanical tests conducted in accordance with Test Methods and Definitions A 370.

9. Dimensions and Permissible Variations

9.1 Tolerances for thickness, width, and camber applicable to magnetic lamination steels are shown in Table 2, Table 3, and Table 4.

9.2 *Thickness Variations*—The average thickness of the material supplied shall be as close as possible to the order thickness. Measurements made with a contacting micrometer at points no closer than ⅜ in. (10 mm) from the edge of a sheet or coil of specified width shall not differ from the specified thickness by more than the value (which includes taper) shown in Table 2.

9.3 *Taper*—The rolling of flat rolled sheets inherently produces an edge which is thinner than the rest of the sheet. This characteristic is termed tapered edge or feather or gamma and

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

NOTE 1— Core-loss values are developed after quality development anneal (QDA) at approximately 1450°F (790°C) to obtain thoroughly decarburized (<0.005 % carbon) Epstein test specimens (with one half cut parallel and the other half cut perpendicular to the direction of rolling).

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

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

TABLE 2 Thickness Tolerances, Cold-Rolled Sheet, Magnetic Lamination Steel for Specified Width 2 to 60 in. (50 to 1520 mm) Inclusive[A]

Specified Thickness		Thickness Tolerance, Over and Under	
in.	(mm)	in.	(mm)
Over 0.039 to 0.057 incl	(over 0.99 to 1.45 incl)	0.004	(0.10)
Over 0.019 to 0.039, incl	(over 0.48 to 0.99 incl)	0.003	(0.08)
Over 0.014 to 0.019, incl	(over 0.36 to 0.48 incl)	0.002	(0.05)

[A] Thickness is measured at any point across the width not less than ⅜ in. (10 mm) from a side edge.

TABLE 3 Width Tolerances, Cold-Rolled Sheet, Magnetic Lamination Steel[A]

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)	0.125	(3.2)	0	0
Over 30 to 48, incl	(over 760 to 1220, incl)	0.188	(4.8)	0	0
Over 48 to 60, incl	(over 1220 to 1520, incl)	0.250	(6.4)	0	0

[A] Width tolerances for 2 to 12 in. (50 to 300 mm) inclusive apply to widths produced by slitting from wider sheet coils.

occurs primarily within 1 or 2 in. (25 or 50 mm) from the as-rolled edge of the material. The thickness variation, classified as edge taper, is often the major portion of the total overall thickness variation permitted in 9.2. It may be expected that in the case of edge slit coils, the following limits on the differences in thickness measured within the first 2 in. (50 mm) or less from either edge of the ordered width will apply:

Ordered Thickness in.	(mm)	Maximum Taper in.	(mm)
0.0185	(0.47)	0.0012	(0.030)
0.025	(0.64)	0.0014	(0.035)

More restricted cross-width thickness tolerances shall be negotiated between the producer and the user.

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TABLE 4 Camber Tolerances, Cold-Rolled Sheet, Magnetic Lamination Steel[A,B]

Coil Width		Camber Tolerance	
in.	(mm)		
2 to 12, incl	(50 to 300, incl)	¼ in. to any 8 ft	(6.4 mm to any 2.4 m)
Over 12 to 60, incl	(over 300 to 1250, incl)	1 in. to any 20 ft	(25 mm to any 6.1 m)

[A] Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straight edge.
[B] The tolerance of 2- to 12-in. (50- to 300-mm) inclusive widths applies to those coils slit from wider sheet coils.

9.4 Because of the special processing treatments used for these steels, ordinary flattening operations used for other steel products may not be used due to their effects on magnetic properties. Special flatness requirements for a particular application should be made known on the purchase order.

10. Workmanship, Finish, and Appearance

10.1 The steel shall have a workmanlike appearance and shall be reasonably free of imperfections of a nature or degree that will be detrimental to the fabrication of the finished lamination. Coils may contain some abnormal imperfections which render a portion of the coil unusable because the inspection of coils does not afford the producer an opportunity to remove portions containing imperfections.

10.2 Magnetic lamination steel is supplied with a surface texture produced by rolling on mill rolls which have been roughened by mechanical, chemical, or electrical means to various degrees of surface texture. The roughened textures promote decarburization and minimize sticking during the lamination anneal. Depending upon the application requirements, surface roughness is usually within the range from 40- to 160-µin. (1.0- to 4.0-µm) arithmetic average (R_A) at 0.030-in. (0.76-mm) cutoff and 0.125-in./s (3.2-mm/s) tracing speed and a minimum 1-in. (25-mm) stroke.

10.3 Cut edges made at the continuous pickler before cold reduction (non-side trimmed last) will be furnished unless otherwise specified.

10.4 Magnetic lamination steel is customarily furnished not oiled (dry). If it is to be oiled, it must be so specified.

11. Sampling

11.1 Tests for magnetic properties, when required, shall be taken in a manner to assure representative sampling of the test lot. For quality control purposes, a test lot comprises one heat and it is usual practice to sample one coil from a cast or heat. Frequency of sampling when magnetic properties are guaranteed shall be subject to negotiation.

12. Test Methods

12.1 Tests shall be conducted for magnetic properties in accordance with the procedure of Test Method A 343/A 343M.

12.2 Prepare test specimens from lengths cut from one or both ends of a coil with one half of the specimens cut parallel and the other half perpendicular to the direction of rolling.

12.3 For quality control purposes and grading in accordance with core-loss specifications, give the specimen strips to be tested a controlled quality development anneal (QDA) in a decarburizing atmosphere. The anneal shall be made under conditions that ensure that the specimen strips reach a temperature of 1450°F (790°C) 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 +55°F (13°C). Take care to maintain the strips flat in the anneal and permit ready access of the atmosphere to the edges of the specimen strips.

12.4 Calculate the assumed density for test purposes from the steel chemical composition as follows:

(%Si + 1.7 × % Al)	Assumed Test Density g/cm³	(kg/m³)
0.00–0.65	7.85	(7850)
0.66–1.40	7.80	(7800)
1.41–2.15	7.75	(7750)

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected by the user. The rejection shall be reported to the producer promptly and in writing. The reject material shall be set aside, adequately protected, and correctly identified.

13.2 The producer may make claim for a rehearing. In this event, the user shall make samples that are representative of the rejected material available to the producer for evaluation.

14. Packaging and Package Marking

14.1 Unless otherwise specified, the steel shall be packaged and loaded in accordance with Practices A 700.

14.2 As a minimum requirement, the material shall be identified by having the producer's order number and material identification legibly shown on a tag attached to each coil or shipping unit.

15. Keywords

15.1 carbon steel sheet; cold-rolled magnetic lamination steel; lamination steel; semiprocessed

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APPENDIX

(Nonmandatory Information)

X1. TYPICAL VALUES OF RELATIVE PEAK PERMEABILITY FOR HIGHER QUALITY CORE-LOSS TYPES

X1.1 Typical values appear in Table X1.1.

TABLE X1.1 Core-Loss Types, Maximum Core-Loss Values, and Typical Values of Relative Peak Permeability at 15 Kilogauss (1.5 T) and 60 Hz

NOTE 1—Core-loss values are developed after quality development anneal (QDA) at approximately 1450°F (790°C) to obtain thoroughly decarburized (<0.005 % carbon) Epstein test specimens (with one half cut parallel and the other half cut perpendicular to the direction of rolling).
NOTE 2—Maximum core-loss values at 50 Hz are 0.79 × maximum core-loss values at 60 Hz.
NOTE 3—The production practice for the 47D175 grade typically included hot band annealing hence the reason for the permeability increase over the 47D190 grade.

Sheet Thickness, in. (mm)	Core-Loss Type	Maximum Core Loss, W/lb	Maximum Core Loss, W/kg	Typical Peak Permeability
0.0185 (0.47)	47D175	1.75	3.86	2000
	47D190	1.90	4.19	1800
	47D215	2.15	4.74	2200
	47D270	2.70	5.95	2550
	47D330	3.30	7.28	2600
	47D380	3.80	8.38	2600
0.022 (0.56)	56D230	2.30	5.07	2200
	56D260	2.60	5.73	2300
	56D310	3.10	6.84	2650
	56D380	3.80	8.38	2650
	56D440	4.40	9.70	2650
0.025 (0.64)	64D260	2.60	5.73	2300
	64D290	2.90	6.40	2400
	64D360	3.60	7.94	2650
	64D430	4.30	9.48	2650
	64D490	4.90	10.8	2650
0.028 (0.71)	71D410	4.10	9.04	2650
	71D480	4.80	10.6	2650
	71D550	5.50	12.1	2650
0.031 (0.79)	79D450	4.50	9.92	2650
	79D540	5.40	11.9	2650
	79D610	6.10	13.5	2650

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