Designation: A 901 – 03

Standard Specification for Amorphous Magnetic Core Alloys, Semi-Processed Types[1]

This standard is issued under the fixed designation A 901; 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 general requirements to which flat-cast, amorphous, semi-processed, iron-base magnetic core alloys must conform.

1.2 These alloys are produced by a rapid-quenching, direct-casting process, resulting in metals with noncrystalline structure. The metallic alloys are made to meet specified maximum core-loss values and are intended primarily for commercial power frequency (50- and 60-Hz) applications in magnetic devices. Desirable core-loss and permeability characteristics are developed by further heat treatment in a magnetic field by the purchaser.[2] The heat treatment typically consists of heating the material to a temperature of 320 to 420°C in a dry, inert atmosphere for 5 to 10 min, although soak times of up to 2 h may be used for large transformer cores. A magnetic field may be required during annealing as designated by the producer. Exact optimum annealing conditions depend on the processing of the material and the size and shape of the device.

1.3 Some of these alloys are sensitive to mechanical stress. Care must be exercised in minimizing any stresses on the material in its final application, otherwise, its magnetic properties will be impaired significantly.

1.4 This specification is developed to aid in the purchase of transformer grade amorphous strip. It provides the chemical, physical, and magnetic parameters and procedures for quality control tests.

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.

NOTE 1—For more information on procedures associated with this specification, refer to the following: Practices A 34/A 34M, A 664, A 700, and B 490; Test Methods A 370 and A 773.

1.6 *This standard does not purport to address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 34/A 34M Practice for Sampling and Procurement Testing of Magnetic Materials[3]

A 340 Terminology of Symbols and Definitions Relating to Magnetic Testing[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 664 Practice for Identification of Standard Electrical Steel Grades in ASTM Specifications[3]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[5]

A 712 Test Method for Electrical Resistivity of Soft Magnetic Alloys[3]

A 773 Test Method for dc Magnetic Properties of Materials Using Ring and Permeameter Procedures with dc Electronic Hysteresigraphs[3]

A 900 Test Method for Lamination Factor of Amorphous Magnetic Strip[3]

B 490 Practice for Micrometer Bend Test for Ductility of Electrodeposits[6]

C 693 Test Method for Density of Glass by Buoyancy[7]

D 3455 Test Methods for Compatibility of Construction Materials with Electrical Insulating Oil of Petroleum Origin[8]

3. Terminology

3.1 The terms and symbols used in this specification are defined in Terminology A 340.

[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 May 10, 2003. Published June 2003. Originally approved in 1990. Last previous edition approved in 1997 as A 901 – 97.

[2] The process of heat treatment in a magnetic field is covered by a patent held by General Electric Co. Interested parties are invited to submit information regarding the identification of acceptable alternatives to this patented item to the Committee on Standards, ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[3] *Annual Book of ASTM Standards*, Vol 03.04.
[4] *Annual Book of ASTM Standards*, Vol 01.03.
[5] *Annual Book of ASTM Standards*, Vol 01.05.
[6] *Annual Book of ASTM Standards*, Vol 02.05.
[7] *Annual Book of ASTM Standards*, Vol 15.02.
[8] *Annual Book of ASTM Standards*, Vol 10.03.

4. Dimensions

4.1 *Width*—Tolerances on nominal as-cast strip shall be +0.004, −0.020 in. (+0.1 mm, −0.5 mm) from specified purchase width.

4.2 *Thickness*—The nominal thickness shall be 0.001 in. (0.025 mm) as measured by a 0.25-in. (6.35-mm) diameter anvil micrometer. The nominal thickness may vary ±0.0002 in. (±0.005 mm), but the maximum thickness variation across the width shall be within ±10 % of the mean thickness, or as agreed upon between the purchaser and the producer.

5. Material Requirements

5.1 Amorphous magnetic core alloys are composed principally of iron with small amounts of alloying elements such as boron and silicon. Other chemical elements are in residual amounts or can be added to improve fabrication or the physical or magnetic properties. The producer shall provide, on request, a statement of the nominal chemistry being supplied. The nominal composition for one particular alloy, in weight percent, is: iron 92, silicon 5, and boron 3.

6. Sampling

6.1 A continuously cast strip in one coil without breaks will constitute one test lot. In practice, this may represent quantities up to 2200 lb (1000 kg), depending on the width of the strip.

6.2 Test samples normally shall be taken from both ends of the continuous strip of each test lot. Other sample frequencies may be used as agreed upon by the producer and the purchaser.

6.3 For small coils, less than 100 lb (45 kg), and for coils containing splices, the test lot shall be as agreed upon between the producer and the purchaser.

7. Physical and Mechanical Property Requirements

7.1 *Density*—The density shall be provided by the producer to a precision of ±0.05 g/cm^3(±50 kg/m^3) as measured by Test Method C 693.

7.2 *Ductility*—Strip bend ductility, with free solidification surface facing inward, shall be such that a minimum 1-m length of ribbon may be passed 180° around a 0.125-in. (3-mm) polished steel rod without cracking or fracture.

7.3 *Thermal Expansion*—The nominal coefficient of thermal expansion shall be reported for the temperature range 40 to 400°C.

7.4 *Thermal Conductivity*—The nominal value measured across the width shall be reported for temperatures of 25, 100, and 400°C. The defined thermal conductivity of the material shall not differ from the reported value by more than ±20 %.

7.5 *Volume Resistivity*—The nominal volume resistivity shall be reported as measured by Test Method A 712.

7.6 *Lamination Factor*—The minimum lamination factor of uncoated material shall be 77 % as measured in accordance with Test Method A 900. The lamination factor for coated material shall be as agreed between the producer and the purchaser.

7.7 *Surface*—The strip surface and edges shall have no wrinkles, dimples, cracks, folds, flakes, or other injurious imperfections that would make the material unsuitable for the fabrication of transformer cores.

7.8 *Edge*—The strip edge shall have no slivers with a maximum dimension exceeding 0.004 in. (0.1 mm).

7.9 *Camber*—The strip edge shall show no excessive lateral curvature (camber). Maximum deviation from a straight line of an 8-ft (2.4-m) strip edge shall not exceed 0.1 in. (2.5 mm).

7.10 *Pinholes*—The strip shall have no pinholes exceeding 0.08 in. (2.0 mm). Maximum hole frequency, visible against a light source, shall not be more than 1 per 3 in.^{2} (19.4 × 10^{-4} m^2).

8. Magnetic Property Requirements

8.1 *Test Procedure*—The magnetic quality of each batch of material (as defined in 6.1) shall be determined by obtaining test samples from both ends of a batch (or lot). These samples shall be annealed in a dry, inert atmosphere with an applied magnetic field of at least 10 Oe (800 A/m) using the time and temperature sequence recommended by the producer. The samples may be either in toroidal or flat strip form as agreed upon between the producer and the purchaser.

8.2 Amorphous magnetic core alloys are purchased to specified maximum core loss requirements. The purchaser shall make clear to the producer the limiting values of core loss required for the ordered material. For the nominal composition given in 5.1, the guaranteed maximum core loss is shown in Table 1.

8.3 Depending upon the desired end use, other magnetic properties such as specific exciting power, saturation induction, residual induction, and coercive field strength may need to be specified. The purchaser is responsible for specifying the limits on magnetic properties. The purchaser shall also state whether and what specific tests are required. The guaranteed magnetic properties for the nominal composition given in 5.1 are shown in Table 1.

9. Product Uniformity Verification

9.1 Since it is assumed that the process will give "essentially identical properties to all parts of a coil," and that test samples are taken at only both ends of a coil, it remains for the producer to verify the uniformity of this product. At regular time intervals, the producer shall perform appropriate tests at

TABLE 1 Magnetic Property Requirements for the Nominal Composition of $Fe_{92}B_3Si_5$

Test Temperature, °C	Minimum DC Induction, @ H_m = 10 Oe (800 A/m)	Maximum DC Coercive Field Strength (H_c) @ H_m = 1 Oe (80 A/m)	Minimum DC Residual Induction (B_r) @ H_m = 1 Oe (80 A/m)	Maximum 60 Hz Core Loss ($P_{c(B:f)}$) @ 14.0 kG (1.40 T)	Maximum 60 Hz Specific Exciting Power ($P_{z(B:f)}$) @ 14.0 kG (1.40 T)
25	15.4 kG (1.54 T)	40 mOe (3.2 A/m)	12.0 kG (1.20 T)	0.114 W/lb (0.251 W/kg)	0.50 VA/lb (1.1 VA/kg)
85	14.7 kG (1.47 T)	—	—	—	—
100	14.5 kG (1.45 T)	—	—	—	—

regular (length) intervals to verify the uniformity of magnetic and mechanical properties throughout the length of a coil.

9.2 Verification of uniformity test results as obtained in 9.1 shall be made available to the purchaser when requested.

10. Packaging and Marking

10.1 The strip shall be free from rust, fingerprints, and grease. No continuous indication of oxide shall be visible along the surface or edges of the strip.

10.2 *Spool*—The inside diameter of the spool hub shall be 9.0 ± 0.1 in. (229 ± 3 mm). The outside diameter of the strip wound on this spool shall be at least 30 in. (762 mm) and shall not exceed 35 in. (890 mm).

10.3 There shall be no more than three breaks in the strip per spool. At any break, the strip ends shall be sheared square, butted, and joined with tape which shall extend substantially across the width of the strip, but not beyond the strip edges.

10.3.1 The tape shall have the following characteristics: tape thickness no greater than the strip thickness; tape base material and adhesive capable of withstanding the normal core-annealing cycle without significant detriment to tape and strip; tape tensile strength and adhesive shear strength sufficient to withstand normal core-processing tension and acceleration; and tape base material and adhesive compatible with transformer oil when tested in accordance with Test Method D 3455.

10.4 The strip shall be manufactured and wound on the spool in a manner such that, when the strip is removed from the spool, the edge of the strip will be perpendicular to the axis of the spool with no tendency to curve to one side.

10.5 The strip shall be packed to prevent physical damage during shipment. The packaging techniques used shall permit weather-protected storage at the purchaser's site for a period of six months without degradation of the material.

10.6 The amorphous metal will be placed on a pallet with the spool axis perpendicular to the pallet allowing handling by fork truck. Unpacking will involve only strap cutting and no nail withdrawal.

10.7 *Marking*—To provide traceability, each spool shall be marked, in an agreed manner, with reference number allowing identification of the material cast.

11. Testing

11.1 *Test Reports*—The producer shall furnish certified test reports assuring compliance with the requirements of this specification.

11.2 *Rejection*—After establishment of a mutually acceptable sampling and test procedure, the purchaser may, at his option, sample test incoming material for any characteristic defined by this specification and accept or reject material based upon these sample tests.

12. Keywords

12.1 amorphous; coercive field strength; core loss; induction; residual induction; specific exciting power

APPENDIX

(Nonmandatory Information)

X1. TYPICAL PHYSICAL PROPERTIES

X1.1 Typical physical properties for the composition given in 5.1 are listed in Table X1.1. The data provided are for information only and are not requirements in this specification.

TABLE X1.1 Typical Physical Properties

NOTE 1—Impurities, particularly carbon, play a major role in the aging of electrical steels, the principal cause for which are interstitial migration and grain boundary precipitation. Accelerated (200 days at 543K) and long-term (14 years at 400K) aging studies have shown that the aging characteristics of metallic glasses (that is, amorphous magnetic core alloys) are not adversely influenced by the presence of carbon in the alloy chemistry. The likely reason for this is that amorphous alloys do not contain either crystals or grain boundaries. See Ramanan, V.R.V., et al., *Journal of Applied Physics*, Vol 73, No. 10, May 15, 1993, p. 5366.

Density	7.20 ± 0.05 g/cm^3 (7200 ± 50 kg/m^3)
Thermal expansion	6 µm/m·K
Thermal conductivity	0.014–0.024 cal/(s·cm·°C) (6 to 10 W/(m·K))
Volume resistivity	120 µΩ·cm (1.20 × 10^{-6} Ω·m)
Crystallization temperature[A]	550°C
Curie temperature[A]	420°C

[A] Determined by differential scanning calorimetry (DSC) at a heating rate of 20°C/min.