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An American National Standard

Standard Specification for Low-Carbon Magnetic Iron[1]

This standard is issued under the fixed designation A 848/A848M; 848; 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 requirements for wrought low-carbon iron having a carbon content of 0.015 % or less with the remainder of the analysis being substantially iron.

1.1.1 Two alloy types are covered: Type 1 is a low-phosphorous grade and Type 2 contains a phosphorous addition to improve machinability.

1.2 This specification also covers alloys supplied by a producer or converter in the form and condition suitable for fabrication into parts which will be subsequently heat treated to create the desired magnetic characteristics. It covers alloys supplied in the form of forging billets, hot-rolled products, and cold-finished bar, wire, and strip.

1.3 This specification does not cover iron powders capable of being processed into magnetic components.

1.4 This specification does not cover flat-rolled, low-carbon electrical steels.

1.5 The values stated in either customary (absolute (or practical) cgs-emu (cgs-emu and inch-pound) units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated given in each system parentheses are mathematical conversions to SI units which are provided for information only and are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.Figs. X1.1-X1.3 considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*

[1] This specification is under the jurisdiction of ASTM Committee A-6 A06 on Magnetic Properties and is the direct responsibility of Subcommittee A06.02 on Materials Specifications.

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A 34/A 34M Practice for Procurement, Testing, and Sampling and Procurement Testing of Magnetic Materials[2]
A 341/A 341M Test Method for Direct Current Magnetic Properties of Materials Using dc D-C Permeameters and the Ballistic Test Methods[2]
A 596/A 596M Test Method for Direct-Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens[2]
A 773/A 773M Test Method for dc Magnetic Properties of Materials Using Ring and Permeameter Procedures with dc Electronic Hysteresigraphs[2]

2.2 *Other:*

IEC Publication 60404-7 Ed. 1 Method of Measurement of the Coercivity of Magnetic Materials in an Open Magnetic Circuit[3]

3. Ordering Information

3.1 Orders to this specification shall include as much of the following information as is required to describe the desired material:

3.1.1 ASTM specification number and alloy type.

3.1.2 *Dimensions and Tolerances*—The tolerances are to be mutually agreed upon between the consumer user and the producer.

3.1.3 Quantity (weight or number of pieces).

3.1.4 Form and condition

3.1.5 Magnetic property requirements if they are otherwise than stated herein.

3.1.6 Certification of chemical analysis or magnetic property evaluation, or both.

3.1.7 Marking and packaging

3.1.8 *End Use*—Whenever possible, the consumer user should specify whether the product will be machined, blanked into flat pieces, blanked and formed, or deep drawn to shape. This information will help the producer provide the most suitable product for the consumer's user's fabrication practice.Table X1.1 practice.

3.1.9 Exceptions to this specification or special requirements.

4. Chemical Composition

4.1 Alloys supplied to this specification shall conform to the requirements in Table 1. Three of the elements listed in Table 1, namely vanadium, titanium, and aluminum, are not required but may be added to suppress magnetic aging. If present, they must be analyzed and reported.

5. Form and Condition

5.1 These two alloys are capable of being produced in a wide variety of forms and conditions for fabrication into magnetic components. The desired form and condition shall be discussed with the producer to assure receiving the correct product. Available forms and conditions are:

5.1.1 *Forging Billet*—Hot- worked and surface conditioned by grinding.

5.1.2 *Hot-Rolled Product*—Hot- rolled; hot- rolled and acid- cleaned; hot- rolled and annealed; hot- rolled, annealed, and acid-cleaned; hot- rolled and mechanically cleaned; mechanical properties as specified.

5.1.3 *Cold-Finished Bars*—Cold- drawn, centerless ground, mechanical properties as specified; or relay condition.

5.1.3.1 *Relay condition* applies to 1 in. [(25.4 mm]) round and less in diameter and certain shapes supplied in the cold-worked condition having up to 25 % reduction in area and capable of meeting Class 2 magnetic property requirements as defined in 6.5.

5.1.4 *Strip*—Cold- rolled, cold- rolled and annealed, deep draw quality, mechanical properties as specified; or relay condition.

5.1.4.1 *Relay condition* applies to cold-rolled strip 0.020 in. [0.51 mm] to 0.200 in. [5.1 mm] (0.51 to 5.1 mm) thick having up to 25 % reduction in thickness and capable of meeting Class 2 magnetic property requirements as defined in 6.5.

[2] Annual Book of ASTM Standards, Vol 03.04.
[3] Available from American National Standards Institute, 11 25 W. 42nd 43rd St., 13th 4th Floor, New York, NY 10036.

TABLE 1 Chemical Requirements (Weight Percent)

	Alloy Type 1	Alloy Type 2
Carbon, max	0.020	0.020
Manganese, max	0.35	0.35
Silicon, max	0.15	0.15
Phosphorous	0.030 max	0.10/0.18
Sulfur, max	0.025	0.025
Chromium, max	0.20	0.20
Nickel, max	0.15	0.15
Vanadium, max	0.10	0.10
Titanium, max	0.10	0.10
Aluminum, max	0.10	0.10
Iron	balance	balance

5.1.4.2 Ordering information for strip must include edge condition and mechanical property requirements.

5.1.5 *Wire*—Cold- drawn, annealed, mechanical properties as specified or relay condition.

5.1.5.1 *Relay condition* applies to cold-drawn wire when capable of being supplied having up to 25 % reduction in area and capable of meeting Class 2 magnetic property requirements as defined in 6.5.

6. Magnetic Property Requirements

6.1 *Density*—The density for test purposes is 7.86 g/cm [7860 ^{3} (7860 kg/m]. ^{3}).

6.2 *Test Specimen*—Whenever possible, test specimen size and shape shall conform to Practice A 34/A 34M. Shapes such as ring laminations, solid rings, Epstein specimens, or straight lengths having a uniform cross section are preferred. If, however, it is impossible to prepare a preferred test specimen shape from the product, specimen shape and size shall be mutually agreed upon by the consumer user and the producer.

6.3 *Heat Treatment*—It is recommended that the consumer user specify the desired heat treatment method to be applied to the test specimens.

6.3.1 When relay condition is specified, the test specimen shall be heat treated in a dry forming gas atmosphere (5 to 15 % hydrogen in nitrogen with a dew point less than −40°C) at a temperature of 845°C for 1 h at temperature and cooled at a rate from 55 to 100°C/h to 500°C and cooled at any rate thereafter.

6.3.2 If relay condition is not specified and no heat-treating procedure is specified by the consumer, user, the producer is free to choose a heat treatment procedure. Refer to Appendix X3 for heat treatment recommendations.

6.4 *Test Method*—Magnetic testing shall be conducted in accordance with Test Methods A 341/A 341M, A 596/A 596M, or A 773/A 773M or by use of a coercimeter. Under this specification only the coercive force (H field strength (H_c) must be measured.

6.5 *Requirements*—The coercive force (H field strength (H_c) measured from a maximum magnetic flux density of 15 kG [1.5 T] (1.5 T) or higher must meet the maximum values listed in Table 2 when the test specimen is heat treated in accordance with 6.3.1.

6.5.1 When a coercimeter is used, the supplier must be able to demonstrate that the flux density in the test specimen reaches at least 15 kG [1.5 T] (1.5 T) during the magnetization cycle. In addition, the test equipment and method should conform to those specified in IEC Publication 60404-7.

7. Packaging and Marking

7.1 Packaging shall be subject to agreement between the producer and the consumer. user.

7.2 Material furnished under this specification shall be identified by the name or symbol of the producer, by alloy type, melt number, and material size. Each lot applied on a given order must be identified and packaged separately.

8. Investigation of Claim

8.1 Where any order fails to meet the requirements of this specification, disposition of the material so designated shall be subject to agreement between the consumer user and the producer.

9. Keywords

9.1 coercive force; field strength; magnetic iron; relay steel

APPENDIXES

(Nonmandatory Information)

X1. TYPICAL MAGNETIC PROPERTIES

X1.1 Typical magnetic properties of these alloys are shown in Fig. X1.1, Fig. X1.2, and Fig. X1.3 and are listed in Table X1.1.. There is no statistically significant difference in magnetic properties between Type 1 and Type 2 alloys for a given product size, condition, and heat treatment. The data provided are for information only and are not requirements in this specification.

TABLE 2 Direct Current Coercive Foield Strcength Requirements

Class 1	0.75 Oe [60 A/m]
Class 1	0.75 Oe (60 A/m)
Class 2 (Relay Condition)	1.0 Oe [80 A/m]
Class 2 (Relay Condition)	1.0 Oe (80 A/m)
Class 3	1.5 Oe [120 A/m]
Class 3	1.5 Oe (120 A/m)

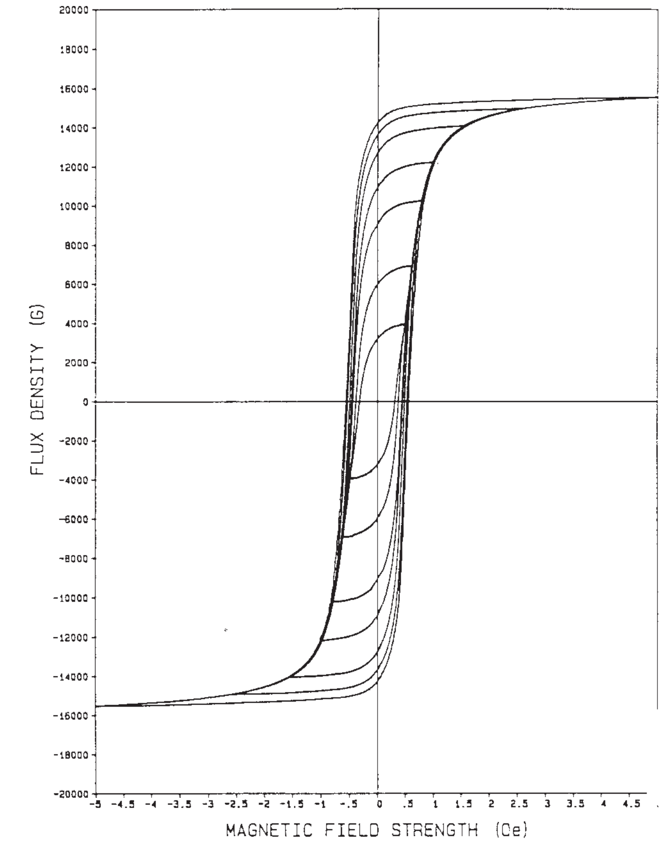

FIG. X1.1 Direct Current Hysteresis Loops for Specimen of Low-Carbon Magnetic Iron Exhibiting Class 1 Behavior. Coercive Field Strength is 0.534 Oe (42.5 A/m)

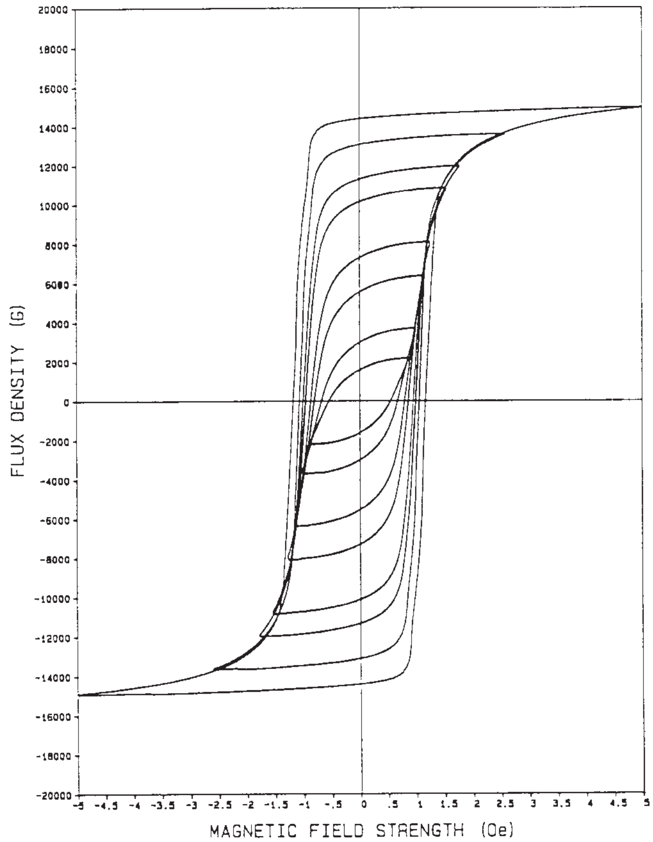

FIG. X1.2 Direct Current Hysteresis Loops for Specimen of Low-Carbon Magnetic Iron Exhibiting Class 3 Behavior. Coercive F~~o~~ield Str~~e~~ength is 1.18 Oe ~~[~~ (93.9 A/m~~]~~)

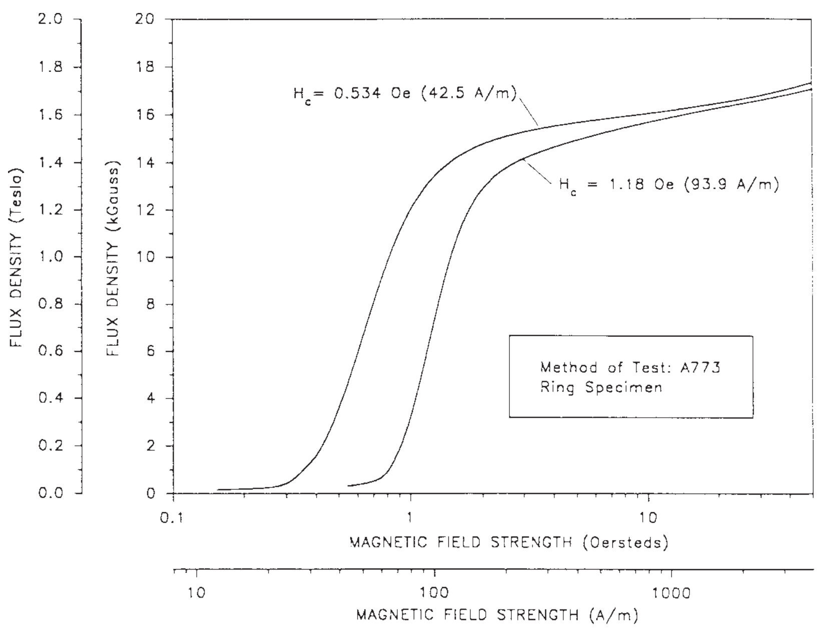

FIG. X1.3 Direct Current Normal Induction Curves to 50 Oe (4 kA/m) for Low-Carbon Magnetic Iron Exhibiting Class 1 and Class 3 Properties

TABLE X1.1 Typical dc Magnetic Properties

NOTE 1—Data for solid ring specimens machined from hot-rolled bar, annealed at 843°C for 4 h in wet hydrogen and tested in accordance with Test Method A 596. Residual induction (BB_r) and coercive foield strength (H_c) are measured from a maximum flux density of 15 kG [(1.5 T]).

Maximum relative permeability	9 400
Maximum relative permeability	9400
Residual induction	14 400 G [1.44 T]
Residual induction	14 400 G (1.44 T)
Coercive force	0.85 Oe [68 A/m]
Coercive field strength	0.85 Oe (68 A/m)

X2. TYPICAL PHYSICAL AND MECHANICAL PROPERTIES

X2.1 Typical physical properties other than magnetic are shown in Table X2.1. Typical mechanical properties are shown in Table X2.2. The data provided in these tables are for information only and are not requirements in this specification.

TABLE X2.2 Typical Room Temperature Mechanical Properties

		0.2 % Offset	Ultimate	
Condition	Hardness	Yield Stress	Tensile Stress	% Elongation
Hot-rolled bar	50 HRB	36 ksi [250 MPa]	46 ksi [320 MPa]	47
Hot-rolled bar	50 HRB	36 ksi (250 MPa)	46 ksi (320 MPa)	47
Relay condition bar	68 HRB	55 ksi [380 MPa]	65 ksi [450 MPa]	15
Relay condition bar	68 HRB	55 ksi (380 MPa)	65 ksi (450 MPa)	15
Annealed bar	55 HRB	40 ksi [280 MPa]	45 ksi [310 MPa]	35
Annealed bar	55 HRB	40 ksi (280 MPa)	45 ksi (310 MPa)	35

X3. HEAT TREATMENT OF LOW-CARBON MAGNETIC IRON

X3.1 Magnetic test specimens shall be heat treated in accordance with the procedure listed in 6.3.1 for qualifying material to meet this specification.

X3.2 Parts fabricated from magnetic iron can be heat treated in several different manners depending on the application and the heat-treating equipment available. General comments regarding the heat- treatment procedure are as follows:

X3.2.1 *Atmosphere*—Decarburizing atmospheres typically result in the lowest coercivity material. The following atmospheres are listed in order of decreasing effectiveness of decarburization:

X3.2.1.1 *Wet Hydrogen*—(dew point from −-20° to 5°C) do not use at temperatures greater than 950°C.

X3.2.1.2 *Wet Forming Gas* (5 to 15 % hydrogen balance nitrogen)—do not use at temperatures greater than 950°C.

X3.2.1.3 *Dry Hydrogen*—(dew point less than −40°C) can be used at all temperatures.

X3.2.1.4 *Dry Forming Gas*—can be used at all temperatures.

X3.2.1.5 *Vacuum*—can be used at all temperatures.

X3.2.1.6 *Endothermic Atmospheres*—carburizing potential is inversely proportional to dew point.

TABLE X2.1 Typical Room Temperature Physical Properties

Specific gravity	7.86
Electrical resistivity	13 μohm·cm [130 μohm·mm]
Electrical resistivity	13 μΩ·cm (130 μΩ·mm)
Specific heat	0.108 cal/g·°C [452 J/kg·K]
Specific heat	0.108 cal/g·°C (452 J/kg·K)
Thermal conductivity	0.175 cal/cm·s·°C [73.2 W/m·K]
Thermal conductivity	0.175 cal/cm·s·°C (73.2 W/m·K)
Thermal expansivity (20–200°C)	12.6 10^{-6}/°C
Saturation flux density	21.5 kG [2.15 T]
Saturation flux density	21.5 kG (2.15 T)
Curie temperature	770°C

X3.3 *Temperature*:

X3.3.1 The lowest suggested heat- treatment temperature is 700°C. These alloys are ferritic up to a temperature of about 890°C. Above this temperature austenite forms. Decarburization is most readily obtained in the ferritic state.

X3.3.2 Heat treatment in the austenite phase (at temperatures above 890°C) will result in grain size refinement upon cooling through the austenite to ferrite transformation. Conversely, heat treatment at very high temperature followed by slow cooling through the transformation will maximize the ferrite grain size thus improving the magnetic properties.

X3.3.2.1 A suggested high temperature heat- treatment procedure is: heat to and hold at 850 ± 25°C for 4 h in wet hydrogen, purge out wet hydrogen with dry hydrogen and heat to 1120°C and hold at temperature for 4 h then cool at a rate of 55 to 100°C per hour to a temperature of 550°C followed by cooling at any convenient rate.

X4. MAGNETIC AGING OF LOW-CARBON MAGNETIC IRON

X4.1 Trace amounts of carbon and especially nitrogen present either in the as-melted material or introduced during processing such as heat treatment in atmospheres containing nascent or atomic nitrogen can cause time-dependent changes in magnetic behavior termed magnetic aging. These changes may occur over a period of weeks or even months at room temperature and are due to the precipitation of nitrides and carbides.

X4.2 Magnetic aging typically impairs magnetic performance, especially in relays. The magnetic properties most subject to aging include low-induction permeability and coercive ~~force.~~ field strength. High-induction properties and magnetic saturation are not measurably affected by magnetic aging.

X4.3 Magnetic aging can be effectively eliminated by use of iron containing trace additions of strong nitride formers such as vanadium, titanium, and aluminum. Vanadium and titanium are also strong carbide formers and will suppress aging ~~due to~~ caused by carbon.

X4.4 Magnetic aging can also be reduced or eliminated by annealing in wet hydrogen to reduce the carbon and nitrogen content and by slow cooling after the anneal.

X4.5 A procedure for determination of the potential for magnetic aging is to measure the coercive ~~force~~ field strength of a freshly heat-treated specimen, heat at 100°C for a period of ~~8~~ eight days to accelerate the aging process and remeasure the coercive ~~force.~~ field strength.

X4.6 The magnetic behavior of parts can be stabilized by heating to 175 to 260°C for several hours to cause overaging. Note that the magnetic properties will be inferior to freshly heat-treated parts, but the time dependency will be largely eliminated.