INTERNATIONAL

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Standard Specification for Low-Carbon Magnetic Iron[1]

This standard is issued under the fixed designation A848; 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 typically having a carbon content of 0.015 % or less with the remainder of the chemical composition 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. Please refer to the following ASTM Standards for information regarding powdered metal materials and magnetic components: Specifications A811, A839, and A904.

1.4 This specification does not cover flat-rolled, low-carbon electrical steels. Please refer to Specification A726 for information regarding these materials.

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 and health 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

A341/A341M Test Method for Direct Current Magnetic Properties of Soft Magnetic Materials Using D-C Permeameters and the Point by Point (Ballistic) Test Methods

A596/A596M Test Method for Direct-Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens

A726 Specification for Cold-Rolled Magnetic Lamination Quality Steel, Semiprocessed Types

A773/A773M Test Method for Direct Current Magnetic Properties of Low Coercivity Magnetic Materials Using Hysteresigraphs

A811 Specification for Soft Magnetic Iron Parts Fabricated by Powder Metallurgy Techniques

A839 Specification for Iron-Phosphorus Powder Metallurgy Parts for Soft Magnetic Applications

A904 Specification for 50 Nickel-50 Iron Powder Metallurgy Soft Magnetic Parts

2.2 *Other:*

IEC Publication 60404-7 Magnetic Materials – Part 7: Method of Measurement of the Coercivity of Magnetic Materials in an Open Magnetic Circuit[3]

3. Terminology

3.1 The terms and symbols used in this specification, unless otherwise noted, are defined in Terminology A340.

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[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.

[3] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

4. Ordering Information

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

4.1.1 ASTM specification number and alloy type.

4.1.2 *Dimensions and Tolerances*—Dimensional tolerances are to be mutually agreed upon between the user and the producer.

4.1.3 Quantity (weight or number of pieces).

4.1.4 Form and condition.

4.1.5 Magnetic property requirements if they are other than stated herein.

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

4.1.7 Marking and packaging.

4.1.8 *End Use*—Whenever possible, the 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 user's fabrication practice.

4.1.9 Exceptions to this specification or special requirements.

5. Chemical Composition

5.1 Alloys supplied to this specification shall conform to the alloy percentage requirements in Table 1. Vanadium, titanium, and aluminum are not required but may be added to suppress magnetic aging; if present, they shall be analyzed and reported and shall meet the requirements in Table 1.

6. Form and Condition

6.1 The two alloy types 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:

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

6.1.2 *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.

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

6.1.3.1 Relay condition applies to round bars of 25.4 mm (1.00 in.) or less in diameter and other special 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 7.5.

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

6.1.4.1 Relay condition applies to cold-rolled strip 0.51 to 5.1 mm (0.020 to 0.20 in.) thick having up to 25 % reduction in thickness and capable of meeting Class 2 magnetic property requirements as defined in 7.5 and Table 2.

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

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

6.1.5.1 *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 7.5 and Table 2.

7. Magnetic Property Requirements

7.1 *Density*—The density for test purposes is 7.86 g/cm^3 (7860 kg/m^3).

7.2 *Test Specimen*—The test specimen size and shape shall conform to Practice A34/A34M. 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 as-manufactured product, specimen shape and size shall be mutually agreed upon by the user and the producer.

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

7.3.1 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 (–40°F)) at a temperature of 845°C (1550°F) for one hour at temperature and cooled at a rate from 55 to 100°C per hour (99 to 180°F per hour) to 500°C (930°F) and cooled at any rate thereafter.

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

7.4 *Test Method*—Magnetic testing shall be conducted in accordance with Test Methods A341/A341M, A596/A596M, or A773/A773M, or by use of a coercimeter as described in 7.5.1. Under this specification only the coercive field strength (H_{cB}) must be measured.

TABLE 1 Chemical Composition 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 to 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

TABLE 2 Maximum Direct Current Coercive Field Strength, H_{cB}

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

7.5 *Requirements*—Coercive field strength, H_{cB}, shall be measured at a magnetic flux density of 1.5 T (15 kG) or higher and must not exceed the required maximum values listed in Table 2 when the test specimen is heat treated in accordance with 7.3.1.

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

8. Packaging and Marking

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

8.2 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 supplied on a given order must be identified and packaged separately.

9. Rejection and Rehearing

9.1 Parts that fail to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer promptly and in writing. In case of dissatisfaction with the results of the test, the producer may make a claim for a rehearing.

9.2 The disposition of rejected parts shall be subject to agreement between the producer and user.

10. Keywords

10.1 coercive 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. Fig. X1.1, Fig. X1.2, and Fig. X1.3 include supplemental *x*-axes showing magnetic field strength in oersteds, Oe, to maintain informational references to these charts in prior versions of this specification.

TABLE X1.1 Typical dc Magnetic Properties

NOTE 1—Data for solid ring specimens machined from hot-rolled bar, annealed at 843°C (1550°F) for four hours in wet hydrogen and tested in accordance with Test Method A596/A596M. Residual induction (B_r) and coercive field strength, H_{cB}, are measured from a maximum flux density of 1.5 T (15 kG).

Maximum relative permeability	9400
Residual induction	1.44 T (14.4 kG)
Coercive field strength	68 A/m (0.85 Oe)

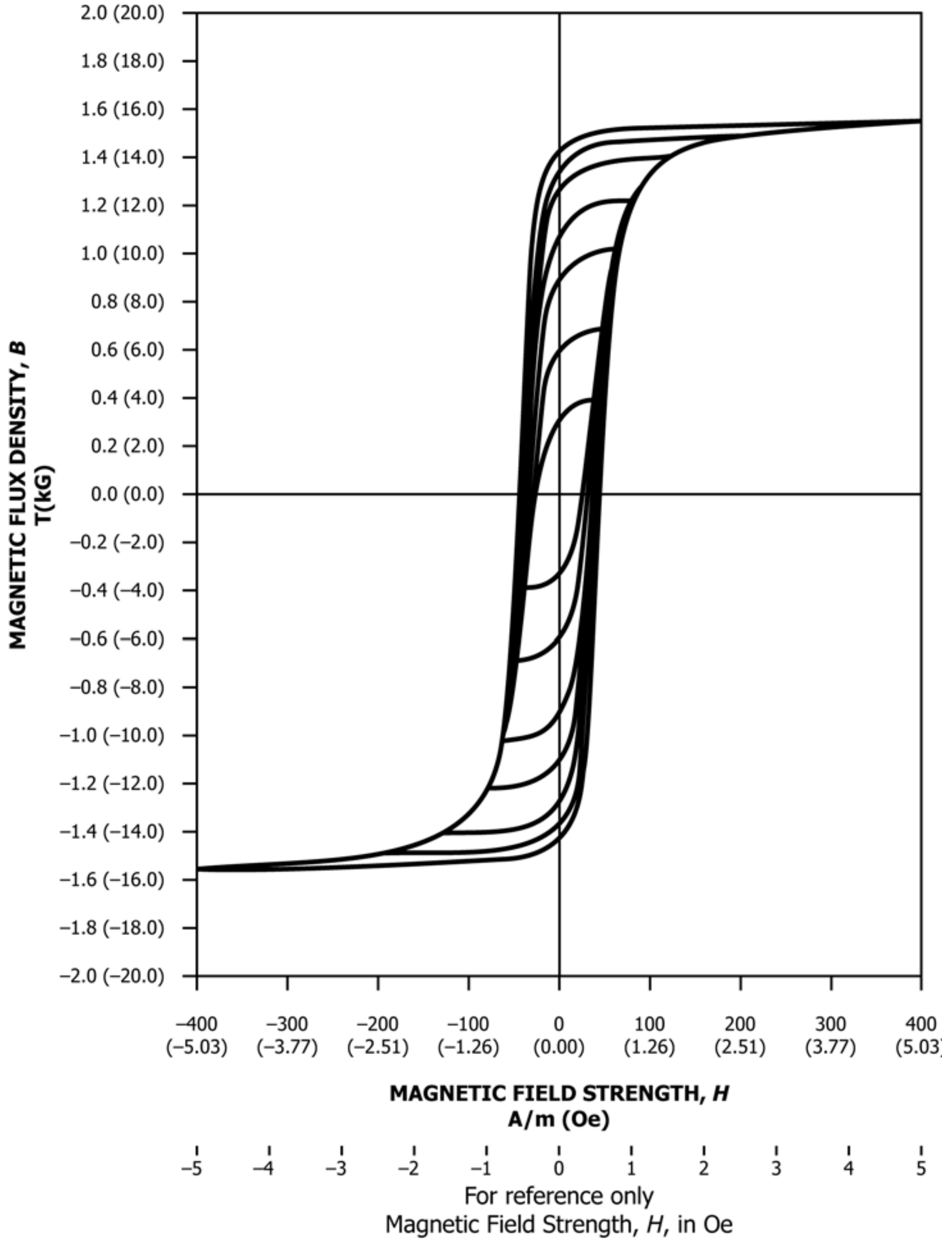

FIG. X1.1 Direct Current Hysteresis Loops for Specimen of Low-Carbon Magnetic Iron Exhibiting Class 1 Behavior. Coercive Field Strength, H_{cB}, is 42.5 A/m (0.534 Oe)

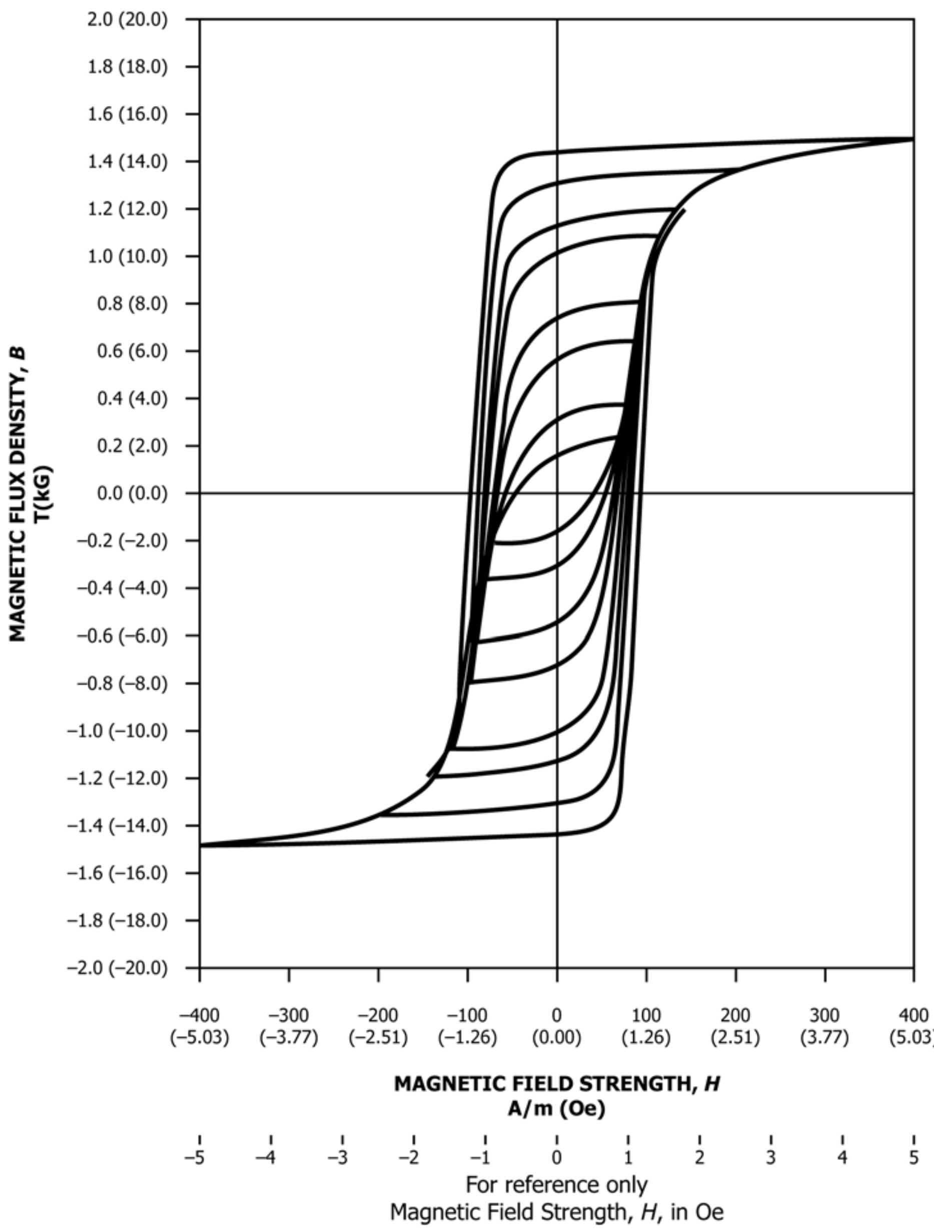

FIG. X1.2 Direct Current Hysteresis Loops for Specimen of Low-Carbon Magnetic Iron Exhibiting Class 3 Behavior. Coercive Field Strength, H_{cB}, is 93.9 A/m (1.18 Oe)

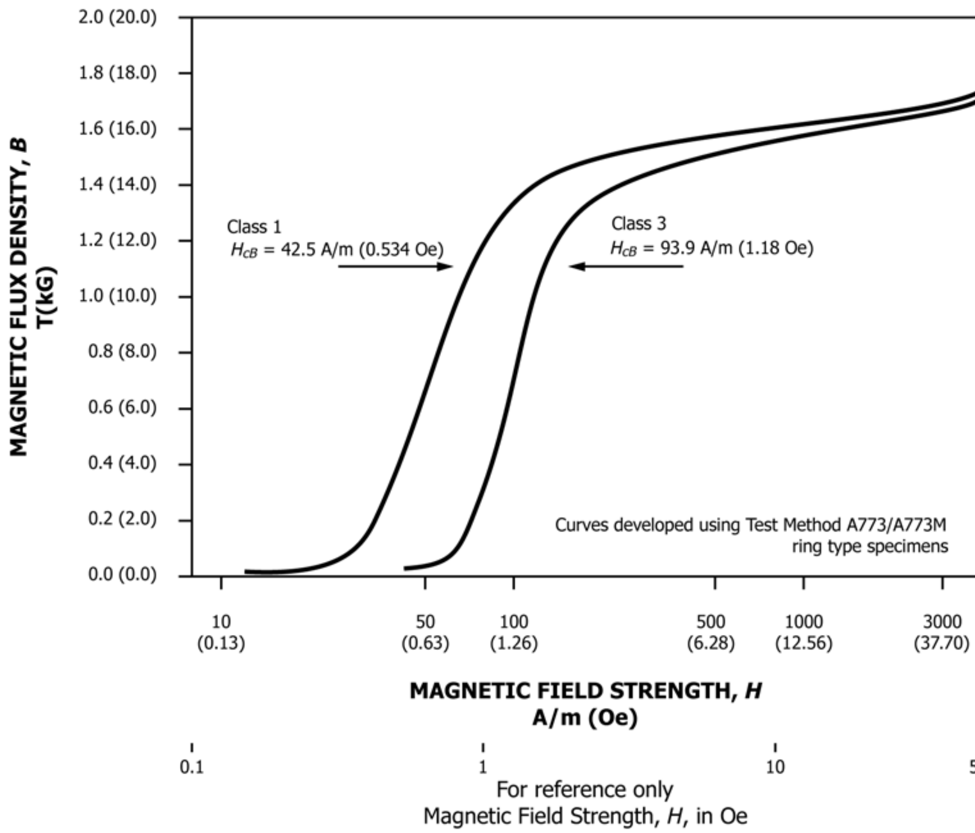

FIG. X1.3 Direct Current Normal Induction Curves to 4000 A/m (50 Oe) for Low-Carbon Magnetic Iron Exhibiting Class 1 and Class 3 Properties

X2. TYPICAL ADDITIONAL PROPERTIES

X2.1 Typical physical properties 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 X2.1 Typical Room Temperature Physical Properties

Specific gravity	7.86
Electrical resistivity	0.13 µΩ·m (13 µΩ·cm)
Specific heat	452 J/kg·K (0.108 cal/g·°C)
Thermal conductivity	73.2 W/m·K (0.175 cal/cm·s·°C)
Thermal expansivity (20–200°C)	12.6 10^{-6}/°C (7.0 10^{-6}/°F)
Saturation flux density	2.15 T (21.5 kG)
Curie temperature	770°C (1418°F)

TABLE X2.2 Typical Room Temperature Mechanical Properties

Condition	Hardness	0.2 % Offset Yield Stress	Ultimate Tensile Stress	% Elongation
Hot-rolled bar	50 HRB	250 MPa (36 ksi)	320 MPa (46 ksi)	47
Relay condition bar	68 HRB	380 MPa (55 ksi)	450 MPa (65 ksi)	15
Annealed bar	55 HRB	280 MPa (40 ksi)	310 MPa (45 ksi)	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 7.3.1 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 (–4 to 41°F))—do not use at temperatures greater than 950°C (1740°F).

X3.2.1.2 *Wet Forming Gas* (5 to 15 % hydrogen balance nitrogen)—do not use at temperatures greater than 950°C (1740°F).

X3.2.1.3 *Dry Hydrogen*—(dew point less than −40°C (–40°F)) 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.

X3.3 *Temperature*:

X3.3.1 The lowest suggested heat treatment temperature is 700°C (1290°F). These alloys are ferritic up to a temperature of about 890°C (1635°F). 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 (1635°F)) 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°C ± 25°C (1560°F ± 45°F) for four hours in wet hydrogen, purge out wet hydrogen with dry hydrogen and heat to 1120°C (2048°F) and hold at temperature for four hours then cool at a rate of 55 to 100°C per hour (99 to 180°F per hour) to a temperature of 550°C (1022°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 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 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 field strength of a freshly heat-treated specimen, heat at 100°C (212°F) for a period of eight days to accelerate the aging process and remeasure the coercive field strength.

X4.6 The magnetic behavior of parts can be stabilized by heating to 175 to 260°C (347 to 500°F) 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.