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Standard Specification for Free-Machining Ferritic Stainless Soft Magnetic Alloy Bar for Relay Applications[1]

This standard is issued under the fixed designation ~~A 838/A 838M;~~ A 838; 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] This specification is under the jurisdiction of ASTM Committee A06 on Magnetic Properties and is the direct responsibility of Subcommittee A06.02 on Materials Specifications.

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1. Scope

1.1 This specification covers free-machining ferritic stainless soft magnetic alloy produced or supplied expressly in cold-finished bar form for use in magnetic cores and other parts requiring a high permeability, low-coercivity stainless steel.

1.1.1 This specification does not cover either cast parts or parts produced by powder metallurgy techniques.

1.2 Two specific alloy types are covered. The primary constituents are shown in Table 1. These types have corrosion resistance similar to AISI Type 430F and Type ~~430F ASTM~~ 430F, Specification A 582/A 582M.

1.3 This specification covers only these alloy types supplied in cold-finished bars in cross-sectional shapes such as rounds, squares, hexagons, and octagons with diameters (diagonals) greater than or equal to 0.250 in. ~~[~~ (6.35 mm~~]~~) and less than or equal to 1.625 in. ~~[~~ (41.28 mm~~]~~).[2]

1.4 Certain cold-finished round bar products are capable of being supplied mill annealed to required magnetic properties such as low coercivity. The size range that can be mill annealed is from 0.250 to 1.625 in. ~~[~~ (6.35 to 41.28 mm~~]~~). Other products of these alloys cannot be mill annealed to produce equivalently low coercivity; hence, the final machined parts should be heat treated as recommended by the producer.

1.5 The values stated in ~~either~~ customary (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.~~ considered standard.

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 341/A 341M Test Method for Direct Current Magnetic Properties of Materials Using ~~D-C~~ dc Permeameters and the Ballistic Test Method[3]

A 582/A 582M Specification for Free-Machining Stainless Steel Bars[4]

A 596/A 596M Test Method for Direct- Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens[3]

[2] Other product forms can be supplied to the chemistries listed in this specification; however, all other requirements shall be subject to negotiation between the producer and the ~~purchaser.~~ user.

[3] *Annual Book of ASTM Standards*, Vol 03.04.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

TABLE 1 Alloy Types

Alloy Type	Nominal Composition, Weight Percent				
	Carbon	Chromium	Silicon	Sulfur	Iron
1	0.05	17.5	0.50	0.30	balance
2	0.05	17.5	1.25	0.30	balance

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

E 1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel, and Cobalt Alloys[5]

2.2 *Other Standard:*

IEC Publication 60404-7 "Methods of Measurement of the Coercivity of Magnetic Materials in an Open Magnetic Circuit"[6]

3. Terminology

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

4. Classification

4.1 Two specific alloy types are covered:

4.2 *Grades, Alloy Type 1*—The standard grades of this alloy type are distinguished by the as-supplied condition, coercivity, and nominal mechanical hardness and are listed in Table 2.

4.3 *Grades, Alloy Type 2*—The standard grades of this alloy type are distinguished by the as-supplied condition, coercivity, and nominal mechanical hardness and are listed in Table 3.

5. Ordering Information

5.1 Purchase orders for material under this specification shall include the following information to adequately describe the desired product:

5.1.1 Reference to this specification and year of issue/revision.

5.1.2 Alloy type and grade (Section 4),

5.1.3 Form and condition,

5.1.4 Dimensions and tolerances (Section 9),

5.1.5 Quantity (weight or number of pieces),

5.1.6 Magnetic property requirements if other than shown in this specification.

5.1.7 Certification of analysis or magnetic quality evaluation, or both, if needed,

5.1.8 Marking and packaging, and

5.1.9 Exceptions to the specification or special requirements.

6. Chemical Composition

6.1 The material shall conform to the requirements prescribed in Table 4.

6.2 Determination of metallic constituents shall be by a method acceptable to both the producer and the ~~purchaser.~~ user. Analysis of carbon, nitrogen, sulfur, and oxygen shall be done in accordance with Test Methods E 1019.

7. Form and Condition

7.1 *Cold Finished Bars*—Cold drawn; cold drawn and centerless ground; cold drawn and precision ground; mill annealed and centerless ground; mill annealed and precision ground.

8. Magnetic Property Requirements

8.1 *General*—Material supplied under terms of this specification shall be tested using either ring, permeameter, or coercimeter test methods. Only the coercive field strength (H_c) is subject to specification. Since coercimeters saturate the test specimen before measurement of the coercive field strength, two different sets of coercive field strength requirements, one for ring and permeameter testing and one for coercimeter testing, are given. Unless specified in the purchase order, coercimeter testing shall be the standard test method.

8.2 *Test Specimen*—Test specimen size and shape shall ~~conform to~~ be in accordance with the requirements listed in Practice A 34/A 34M. If tests on heat-treated specimens are requested, all machining operations shall be performed before heat treatment. The cross-sectional area of all specimen types shall be determined by measurement with a micrometer or calipers.

[5] *Annual Book of ASTM Standards*, Vol 03.065.

[6] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

TABLE 2 Grades for Alloy Type 1

Grade	As-Supplied Condition
1	mill annealed
2	mill annealed
3	unannealed, cold drawn

TABLE 3 Grades for Alloy Type 2

Grade	As-Supplied Condition
1	mill annealed
2	unannealed, cold drawn

TABLE 4 Chemical Requirements

Alloy Type	Carbon, max	Manganese, max	Silicon	Phosphorus, max	Sulfur	Chromium	Molybdenum, max	Nickel, max	Iron
1	0.065	0.80	0.30/0.70	0.030	0.25/0.40	17.25/18.25	0.50	0.60	bal
2	0.065	0.80	1.00/1.50	0.030	0.25/0.40	17.25/18.25	0.50	0.60	bal

8.3 *Magnetic Test Specimen Heat Treatment*—When specified on the purchase order, the annealed magnetic properties (also referred to as the magnetic capability) rather than the as-supplied magnetic properties shall be determined. The heat treatment to be used to assess the magnetic capability should be specified by the ~~purchaser.~~ user. If not, the following heat treatment procedure (full anneal) shall be used.

8.3.1 *Atmosphere*—High vacuum or very dry hydrogen (dew point less than −60°C).

8.3.2 *Soak Temperature* (Alloy Type 1)—815 ± 25°C.

8.3.3 *Soak Temperature* (Alloy Type 2)—850 ± 25°C.

8.3.4 *Soak Time*—2-h minimum.

8.3.5 *Cooling*—Furnace cool (50 to 100°C/h) to 400°C then cool to room temperature at any convenient rate.

8.4 ~~*DC*~~*dc Ring and Permeameter Testing*:

8.4.1 Either ring or permeameter test methods may be used. For ring testing, a link-type specimen with its long edge parallel to the bar axis is preferred. Testing of ring or link specimens shall be in accordance with Test Methods A 596/A 596M or A 773/A 773M. Testing of bar specimens on a permeameter shall be in accordance with either Test Methods A 341/A 341M or A 773/A 773M.

8.4.2 *Requirements*—The coercive field strength, when measured from a maximum flux density of 10.0 kG ~~[~~ (1.00 T~~]~~), shall meet the requirements listed in Table 5. Full-anneal requirements refer to specimens heat treated in accordance with 8.3.

8.5 *Coercimeter Testing*:

8.5.1 Coercimeter testing is permitted provided it can be demonstrated that the maximum flux density induced in the specimen exceeds 13 kG ~~[1.30 T]~~ (1.30 T) and that the equipment and procedures used satisfy the requirements of IEC Publication 60404-7.

8.5.2 Any machining before testing shall be done with due care, and only enough material shall be removed to permit insertion of the test specimen into the coercimeter.

8.5.3 *Requirements*—The coercive field strength shall meet the requirements listed in Table 6. Full-anneal requirements refer to specimens heat treated in accordance with 8.3.

9. Dimensions and Tolerances

9.1 Dimensions and tolerances shall be as mutually agreed upon between the ~~purchaser~~ user and the producer.

10. Certification

10.1 When specified in the purchase order or contract, the ~~purchaser~~ user shall be furnished certification that samples

TABLE 5 DC Coercive Field Strength (H_c) Requirements—Ring and Permeameter Testing

Alloy Type	Grade	Bar Diameter Range, in. ~~[~~ (mm~~]~~)	H_c, max
~~1~~	~~1~~	~~≥0.250 [6.35] ≤0.6875 [17.46]~~	~~2.30 Oe [183 A/m]~~
1	1	≥0.250 [6.35] ≤0.6875 [17.46]	2.30 Oe (183 A/m)
		~~>0.6875 [17.46] ≤1.625 [41.28]~~	~~3.00 Oe [239 A/m]~~
		>0.6875 [17.46] ≤1.625 [41.28]	3.00 Oe (239 A/m)
~~1~~	~~2~~	~~≥0.250 [6.35] ≤0.6875 [17.46]~~	~~4.70 Oe [374 A/m]~~
1	2	≥0.250 [6.35] ≤0.6875 [17.46]	4.70 Oe (374 A/m)
		~~>0.6875 [17.46] ≤1.625 [41.28]~~	~~5.00 Oe [398 A/m]~~
		>0.6875 [17.46] ≤1.625 [41.28]	5.00 Oe (398 A/m)
~~1~~	~~3~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~7.00 Oe [557 A/m]~~
1	3	≥0.250 [6.35] ≤1.625 [41.28]	7.00 Oe (557 A/m)
~~1~~	~~full anneal (all grades)~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~2.20 Oe [175 A/m]~~
1	full anneal (all grades)	≥0.250 [6.35] ≤1.625 [41.28]	2.20 Oe (175 A/m)
~~2~~	~~1~~	~~≥0.250 [6.35] ≤0.6875 [17.46]~~	~~2.60 Oe [207 A/m]~~
2	1	≥0.250 [6.35] ≤0.6875 [17.46]	2.60 Oe (207 A/m)
		~~>0.6875 [17.46] ≤1.625 [41.28]~~	~~2.80 Oe [223 A/m]~~
		>0.6875 [17.46] ≤1.625 [41.28]	2.80 Oe (223 A/m)
~~2~~	~~2~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~7.00 Oe [557 A/m]~~
2	2	≥0.250 [6.35] ≤1.625 [41.28]	7.00 Oe (557 A/m)
~~2~~	~~full anneal (all grades)~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~2.60 Oe [207 A/m]~~
2	full anneal (all grades)	≥0.250 [6.35] ≤1.625 [41.28]	2.60 Oe (207 A/m)

TABLE 6 Coercive Field Strength (H_c) Requirements—Coercimeter Testing

Alloy Type	Grade	Bar Diameter Range, in. [mm]	H_c, max
~~1~~	~~1~~	~~≥0.250 [6.35] ≤0.6875 [17.46]~~	~~2.90 Oe [231 A/m]~~
1	1	≥0.250 [6.35] ≤0.6875 [17.46]	2.90 Oe (231 A/m)
		~~>0.6875 [17.46] ≤1.625 [41.28]~~	~~3.60 Oe [286 A/m]~~
		>0.6875 [17.46] ≤1.625 [41.28]	3.60 Oe (286 A/m)
~~1~~	~~2~~	~~≥0.250 [6.35] ≤0.6875 [17.46]~~	~~6.00 Oe [477 A/m]~~
1	2	≥0.250 [6.35] ≤0.6875 [17.46]	6.00 Oe (477 A/m)
		~~>0.6875 [17.46] ≤1.625 [41.28]~~	~~6.60 Oe [525 A/m]~~
		>0.6875 [17.46] ≤1.625 [41.28]	6.60 Oe (525 A/m)
~~1~~	~~3~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~8.50 Oe [676 A/m]~~
1	3	≥0.250 [6.35] ≤1.625 [41.28]	8.50 Oe (676 A/m)
~~1~~	~~full anneal (all grades)~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~2.80 Oe [223 A/m]~~
1	full anneal (all grades)	≥0.250 [6.35] ≤1.625 [41.28]	2.80 Oe (223 A/m)
~~2~~	~~1~~	~~≥0.250 [6.35] ≤0.6875 [17.46]~~	~~3.40 Oe [271 A/m]~~
2	1	≥0.250 [6.35] ≤0.6875 [17.46]	3.40 Oe (271 A/m)
		~~>0.6875 [17.46] ≤1.625 [41.28]~~	~~3.60 Oe [286 A/m]~~
		>0.6875 [17.46] ≤1.625 [41.28]	3.60 Oe (286 A/m)
~~2~~	~~2~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~8.50 Oe [676 A/m]~~
2	2	≥0.250 [6.35] ≤1.625 [41.28]	8.50 Oe (676 A/m)
~~2~~	~~full anneal (all grades)~~	~~≥0.250 [6.35] ≤1.625 [41.28]~~	~~3.40 Oe [271 A/m]~~
2	full anneal (all grades)	≥0.250 [6.35] ≤1.625 [41.28]	3.40 Oe (271 A/m)

representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of test results shall be furnished.

11. Packaging and Package Marking

11.1 Packaging and package marking shall be subject to agreement between the ~~purchaser~~ user and the producer.

11.2 Material furnished under this specification shall be identified by the name or symbol of the producer, by alloy type and grade, or producer's brand name, or a combination thereof, heat number, and material size. Each heat supplied on a given order must be identified separately and packaged separately.

12. Keywords

12.1 coercive field strength; coercivity; ferritic stainless steel; free-machining; relay

APPENDIX

(Nonmandatory Information)

X1. TYPICAL PHYSICAL, MAGNETIC, AND MECHANICAL PROPERTIES

X1.1 Typical physical and magnetic properties are listed in Table X1.1 for the two alloy types contained in this specification. Magnetic property data shown were measured on 0.250- to 0.375-in. (6.35- to 9.52-mm) diameter mill-annealed (Grade 1—both types) bar using a Fahy Permeameter in accordance with Test Method A 341/A 341M. Larger-diameter bars will yield lower maximum permeabilities and residual inductions due to limitations associated with testing large-diameter, relatively high-permeability bars on a permeameter. Typical mechanical property data other than hardness for Grade 1 of both alloy types is shown

TABLE X1.1 Typical Physical and Magnetic Properties

Property	Alloy Type 1	Alloy Type 2
~~Density, g/cm^3 [kg/m^3]~~	~~7.62 [7620]~~	~~7.59 [7590]~~
Density, g/cm^3 [kg/m^3]	7.62 [7620]	7.59 [7590]
Electrical resistivity, μΩ-cm [μΩ-mm]	60.0 [600]	76.0 [760]
~~Mean coefficient of thermal expansion, (0–649°C) [μm/m/°C]~~	~~[11.9]~~	~~[11.9]~~
Mean coefficient of thermal expansion, (0–649°C) (μm/m/°C)	[11.9]	[11.9]
Curie temperature, °C	671	660
Saturation flux density, kG [T]	15.5 [1.55]	15.2 [1.52]
[Relative] maximum permeability	2300	2350
~~Residual induction,[A] kG [T]~~	~~7.54 [0.754]~~	~~7.42 [0.742]~~
Residual induction,[A] kG (T)	7.54 [0.754]	7.42 [0.742]
~~Coercive field strength,[A] Oe [A/m]~~	~~1.80 [143]~~	~~1.64 [130]~~
Coercive field strength,[A] Oe (A/m)	1.80 [143]	1.64 [130]

[A] Residual induction and coercive field strength are determined from a maximum flux density of 10 kG (1.0 T).

in Table X1.2. Typical hardness ranges are given in Table X1.3. The data provided are for information only and are not requirements in this specification and need not be measured.

TABLE X1.2 Typical Mechanical Properties—Grade 1

Property	Alloy Type 1	Alloy Type 2
0.2 % yield strength, ksi [MPa]	45 [310]	50 [350]
Ultimate tensile strength, ksi [MPa]	75 [520]	78 [540]
Percent elongation in 2 in. [50.8 mm]	20	30
Percent reduction in area	60	60

TABLE X1.3 Typical Hardness

Alloy Type	Grade	Typical Hardness
1	1	75 to 82 HRB
1	2	82 to 91 HRB
1	3	85 HRB at midradius 92 HRB at surface
2	1	80 to 88 HRB
2	2	85 HRB at midradius 92 HRB at surface