



Designation: **A867–03 (Reapproved 2013) A867 – 19**

Standard Specification for Iron-Silicon Relay Steels¹

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1. Scope

1.1 This specification covers wrought iron-silicon (Fe-Si) steels that are generally used in the manufacture of electromechanical devices, such as relays and solenoids, requiring higher electrical resistivity, higher permeability, and lower coercivity and residual magnetism than provided by either carbon steels or soft magnetic low-carbon irons. The steels covered in this specification are:

Steel Type	Nominal Composition
1	1.1 % Si-Fe
1F	1.1 % Si-Fe free machining
2	2.3 % Si-Fe
2F	2.3 % Si-Fe free machining
3	4.0 % Si-Fe

1.2 This specification covers steels in the form and condition required for fabrication into parts. The fabricated parts typically require a final heat treatment to obtain the desired magnetic performance. The term mill annealed as used in this specification applies to a heat treatment, typically applied by the producer, intended to improve formability. The mill anneal does not provide the optimum magnetic performance and is not intended to replace the need for the finish annealing of parts.

1.3 This specification covers steels in the form of forging billets, hot-rolled bar and strip, cold-finished bar, wire, and cold-rolled strip in thicknesses up to 0.250 in. (~~6.35 mm~~); 6.35 mm (0.250 in.).

1.4 This specification does not cover electrical sheet steels used in transformer and motor laminations. Please refer to Specifications [A677](#), [A683](#), [A726](#), [A876](#), and [A1086](#) for standards pertaining to these material types.

1.5 This specification does not cover powder metallurgy materials capable of being processed into magnetic core components having similar silicon contents.

1.6 The values stated in ~~inch-pound~~ SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to ~~SI units that~~ customary (cgs-emu and inch-pound) units which are provided for information only and are not considered standard.

1.6.1 There are selected values presented in two units, both of which are in acceptable SI units. These are differentiated by the word “or,” as in “ $\mu\Omega\text{-cm}$, or, $\Omega\text{-m}$.”

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *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](#)

[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](#)

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.

- [A596/A596M Test Method for Direct-Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens](#)
- [A677 Specification for Nonoriented Electrical Steel Fully Processed Types](#)
- [A683 Specification for Nonoriented Electrical Steel, Semiprocessed Types](#)
- [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 Hysteresis-graphs](#)
- [A876 Specification for Flat-Rolled, Grain-Oriented, Silicon-Iron, Electrical Steel, Fully Processed Types](#)
- [A1086 Specification for Thin-Gauge Nonoriented Electrical Steel Fully Processed Types](#)

2.2 *International Electrotechnical Commission Standard*.³

[IEC 60404-7 Magnetic materials. Part 7: Method of measurement of the coercivity of magnetic materials in an open magnetic circuit](#)

3. Ordering Information

- 3.1 Orders to this specification shall include as much of the following information as is required to describe the desired steel:
- 3.1.1 ASTM Specification number and steel 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~~user~~'s fabrication practice, and practice.
 - 3.1.9 Exceptions to this specification or special requirements.

4. Chemical Composition

4.1 The chemical composition requirements are shown in [Table 1](#). Since magnetic and, possibly, mechanical properties are of primary importance, variations in composition from those shown in [Table 1](#) are permitted by mutual agreement between the consumer~~user~~ and the producer.

5. Form and Condition

- 5.1 As the silicon content increases, cold working becomes more difficult, hence, not all product forms are available in each type of steel. The desired form and condition should be specified and discussed with the producer to assure receiving the appropriate product. Available forms and conditions are:
- 5.1.1 *Forging Billet* (all steel types)—Billet surface ground, grit blasted, or acid cleaned.
 - 5.1.2 *Hot-Rolled Product* (all steel types)—Hot rolled, hot rolled and acid cleaned, and hot-rolled and mechanically cleaned.
 - 5.1.3 *Cold-Finished Bars*—Mill annealed, centerless ground (all steel types), cold drawn (all grades up to ~~0.500 in. (12.7 mm)~~ 12.7 mm (0.500 in.) round), cold-processed shapes such as squares, rectangles, hexagons (all types except Type 3), centerless ground, and machine turned.

TABLE 1 Chemical Composition Requirements

NOTE 1—Values in mass percent

	Type 1	Type 1F	Type 2	Type 2F	Type 3
Carbon	0.04 max	0.04 max	0.04 max	0.04 max	0.04 max
Manganese	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max
Silicon	1.10 nom	1.10 nom	2.30 nom	2.30 nom	4.00 nom
Phosphorus	0.05 max	0.10/0.22	0.05 max	0.10/0.25	0.05 max
Phosphorus	0.05 max	0.10 to 0.22	0.05 max	0.10 to 0.25	0.05 max
Sulfur	0.04 max	0.04 max	0.04 max	0.04 max	0.04 max
Aluminum	0.35 max	0.35 max	0.50 max	0.50 max	0.50 max
Iron ^A	balance	balance	balance	balance	balance
Iron ^A	Balance	Balance	Balance	Balance	Balance

^A Iron is not analyzed nor is it reported.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

5.1.4 *Strip* (all types except Type 3)—As-supplied condition must be specified as either cold rolled to a specified hardness or mill annealed. Steel can be supplied in coil form or as straightened and cut to length flat product. Product can be supplied having a rolled edge, either round or flat, or an edge produced by slitting.

5.1.5 *Wire* (all types except Type 3)—Cold drawn, cold drawn and mill annealed in either coils or straightened and cut to length.

6. Magnetic Property Requirements

6.1 Under this specification, only the coercive field strength (H_{ccB}) is required to be measured. This measurement can be done either using ring or permeameter methods or by use of a coercimeter. Since coercimeters saturate the test specimen before measurement of the coercive field strength, two different sets of requirements are necessary, one for ring and permeameter testing and one for coercimeter testing.

6.2 *Test Specimen Heat Treatment*—The test specimen shall be heat treated before testing as follows; heat at $845 \pm 10^\circ\text{C}$ ($1553^\circ\text{F} \pm 18^\circ\text{F}$) for 4 hours in a wet hydrogen atmosphere (dew point of -20 to 5°C) of -20°C to 5°C (-4°F to 41°F) then cool at a rate of 50 to $100^\circ\text{C}/\text{h}$ to 50°C to 100°C per hour (122°F to 212°F per hour) to a temperature less than 540°C (1000°F) followed by further cooling at any convenient rate. For heat treatment of Type 3 steels, dry hydrogen (dew point less than -40°C) than -40°C (-40°F) shall be used instead of wet hydrogen.

6.3 Conventional dc Magnetic Testing:

6.3.1 Either ring or permeameter techniques may be used. For ring specimens either Test Method A596/A596M or Test Method A773/A773M is permitted. For straight-length specimens, either Test Method A341/A341M or Test Method A773/A773M is permitted.

6.3.2 Whenever possible, test specimen size and shape shall conform to Practice A34/A34M. The densities of these steels for testing purposes are listed in Table X1.1.

6.3.3 *Requirements*—The coercive ~~force~~ field strength requirements of specimens heat treated in accordance with 6.2 are shown in Table 2. The coercive field strength shall be measured from a maximum magnetic flux density of 10.0 kG (1.00 T), 1.0 T (10 kG).

6.4 Coercimeter Testing:

6.4.1 Coercimeters are permitted provided it is demonstrated that magnetic flux density in the test specimen reaches at least 15 kG (1.5 T) 1.5 T (15 kG) during the magnetization cycle and that the test method and test equipment satisfy the requirements of IEC 60404-7.

6.4.2 *Requirements*—The coercive field strength requirements of specimens heat treated in accordance with 6.2 and tested using a coercimeter are shown in Table 3.

7. Packaging and Marking

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

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 producer lot applied to an order must be identified and packaged separately.

8. Investigation of Claim Rejection and Rehearing

8.1 Material that fails 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.

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

9. Keywords

9.1 coercive field strength; iron-silicon steel; relay steel

TABLE 2 DC Coercive Field Strength (H_e) Requirements (Conventional Testing)

	Types 1 and 1F	Types 2 and 2F	Type 3
Oe	0.80 max	0.75 max	0.70 max
A/m	64 max	60 max	56 max

TABLE 2 DC Coercive Field Strength (H_{cB}) Requirements (Conventional Testing)

	Type 1	Type 1F	Type 2	Type 2F	Type 3
A/m (Oe)	64 (0.80) max	64 (0.80) max	60 (0.75) max	60 (0.75) max	56 (0.70) max