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Standard Specification for Soft Magnetic Iron Parts Fabricated by Powder Metallurgy (P/M) Techniques[1]

This standard is issued under the fixed designation A 811; 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 parts produced from iron powder metallurgy materials.

1.2 This specification deals with P/M parts in the sintered or annealed condition. Should the sintered parts be subjected to any secondary operation that causes mechanical strain, such as machining or sizing, they should be resintered or annealed.

1.3 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:*

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[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 Material Specifications.

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A 34/A 34M Practice for Sampling and Procurement Testing of Magnetic Materials[2]
A 340 Terminology of Symbols and Definitions Relating to Magnetic Testing[2]
A 596 Test Method for Direct-Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens[2]
A 773 Test Method for ~~D-C~~ dc Magnetic Properties of Materials Using Ring and Permeameter Procedures with ~~D-C~~ dc Electronic Hysteresigraphs[2]
B 328 Test Method for Density, Oil Content, and Interconnected Porosity of Sintered Metal Structural Parts and Oil-Impregnated Bearings[3]
E 1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel, and Cobalt Alloys[4]

3. Terminology

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

4. Ordering Information

4.1 Purchase orders for parts conforming to this specification shall include the following information~~.~~:
4.1.1 Reference to this specification and year of issue/revision~~.~~,
4.1.2 Reference to an applicable part drawing~~.~~,
4.1.3 Quantity required~~.~~,
4.1.4 A critical cross section of the part shall be defined and so indicated on the applicable part drawing. The location of the critical section is by mutual agreement between the purchaser and the producer (6.2)~~.~~,
4.1.5 Magnetic property requirements if they are other than stated in Table 1~~.~~,
4.1.6 Whether certification of chemical analysis or magnetic property evaluation is required (Sections 5 and ~~7).~~ 7),
4.1.7 Marking and packaging requirements (Section 12)~~.~~, and
4.1.8 Exceptions to this specification or special requirements such as functional testing as mutually agreed upon between the producer and the purchaser.

5. Chemical Composition

5.1 The chemical composition of the parts shall conform to the requirements prescribed in Table 2.
5.2 Determination of metallic constituents shall be by a method acceptable to both the producer and the purchaser. Analysis of carbon, oxygen, sulfur, and nitrogen shall be done in accordance with Test Methods E 1019.

6. Sintered Density Requirements

6.1 Magnetic and residual induction of P/M parts strongly depend on density. The density of P/M parts is determined by the compressibility of the powder, the compacting pressure, and sintering practice (temperature, time, and atmosphere).
6.2 Parts produced in conformance with this specification shall have a minimum sintered density of 6.6 g/cm^3~~[~~ (6600 kg/m^3~~]~~) in the critical section of the part. The critical section shall be defined by agreement between the purchaser and the producer.
6.3 Sintered density shall be determined in accordance with Test Method B 328.

7. Magnetic Property Requirements

7.1 Because of the nature of P/M parts production, magnetic testing of each lot is not required by this specification. However, it is strongly recommended that the purchaser require the producer to conduct periodic magnetic evaluations and to certify such results. Such magnetic property evaluations shall be conducted in the following manner.
7.2 When requested, each lot of parts should be sintered with at least one and preferably three ring test specimens which comply with the geometric requirements listed in Practice A 34/A 34M. The ring specimen(s) shall be produced from the same mixed lot of powder used to produce the parts.
7.3 The magnetic properties shall be determined in accordance with Test Methods A 596 or A 773.

[2] *Annual Book of ASTM Standards*, Vol 03.04.
[3] *Annual Book of ASTM Standards*, Vol 02.05.
[4] *Annual Book of ASTM Standards*, Vol 03.06~~5~~.

TABLE 1 Maximum Coercive Field Strength Requirements

Grade	Coercive Field Strength
~~1~~	~~1.8 Oe [140 A/m]~~
1	1.8 Oe (140 A/m)
~~2~~	~~2.0 Oe [160 A/m]~~
2	2.0 Oe (160 A/m)
~~3~~	~~2.3 Oe [180 A/m]~~
3	2.3 Oe (180 A/m)

TABLE 2 Chemical Requirements (weight percent)

Element	%
Carbon, max	0.03
Oxygen, max	0.10
Nitrogen, max	0.01
Others[A]	0.50, max
Iron[B]	balance

[A] Others refers to trace elements which are to be regarded as incidental and not deliberate additions.

[B] Iron is the balance by difference. Quantitative analysis of this element is not required.

7.4 For the purpose of this specification, only the coercive field strength determined from a maximum applied magnetic field strength of 15 Oe (1200 A/m) needs to be determined. Other magnetic properties may be specified by mutual agreement between the purchaser and the producer.

7.5 *Coercive Field Strength Requirements* —Three grades, defined by coercive field strength, are stipulated by this specification and are listed in Table 1. The coercive field strength requirement for Grade 3 was developed from interlaboratory study. The values for Grades 1 and 2 are based on a literature review and are believed to reflect the current industry capabilities.

7.6 *Magnetic Aging*— Nitrogen introduced during sintering can cause time-dependent degradation of magnetic properties. Therefore, when requested by the purchaser, the producer shall test for aging. To determine the susceptibility of the parts to aging, the test ring(s) should be heated for either 100 h at 150 ± 5°C or 600 h at 100 ± 5°C and the coercive field strength remeasured. A change in coercive field strength of 10 % or more of the original value is evidence that aging has occurred.

7.7 Since magnetic properties are strongly affected by process conditions, refer to Appendix X1 for typical values and explanatory notes.

8. Workmanship, Finish and Appearance

8.1 The parts shall be uniform in composition and uniform in density within critical sections.

8.2 If parts are sectioned or fractured, there shall be no readily recognizable defects.

9. Sampling

9.1 A lot shall consist of parts of the same form and dimensions, produced from a single mixed powder batch and from an unchanged process, without discontinuity in production, and submitted for inspection at one time.

9.2 The purchaser and producer shall agree upon a representative number of specimens for testing.

10. Rejection and Rehearing

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

10.2 The disposition of rejected parts shall be subject to agreement between the purchaser and the producer.

11. Certification

11.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have either been tested or inspected as directed in this specification and the requirements have been met.

11.2 When specified in the purchase order or contract, a report of the test results shall include the following:

11.2.1 Chemical composition,

11.2.2 Part density in the critical section,

11.2.3 Magnetic test results, if required by purchaser, and

11.2.4 The results of any other tests stipulated in the purchase order or contract.

12. Packaging and Package Marking

12.1 Packaging shall be subject to agreement between the purchaser and the producer.

12.2 Parts furnished under this specification shall be in a container identified by the name or symbol of the parts' producer.

13. Keywords

13.1 coercive field strength; iron; P/M parts; powder metallurgy (P/M)

APPENDIX

(Nonmandatory Information)

X1. TYPICAL MAGNETIC AND MECHANICAL PROPERTIES

X1.1 Typical magnetic and mechanical properties, based on interlaboratory studies, are listed in Table X1.1, Table X1.2, and Table X1.3. Table X1.1 contains properties typically achieved when sintering is conducted at 1120°C in dissociated ammonia. Table X1.2 contains properties typically achieved when sintering is conducted at 1120°C in dry hydrogen or in a vacuum. Table X1.3 contains properties typically achieved when sintering is conducted at 1260°C in dry hydrogen or in a vacuum. The influence of sintered density is shown in all three tables. The data provided are for information only and are not requirements in this specification.

X1.2 Maximum flux density, residual induction, and coercive field strength are measured from a maximum applied magnetic field strength of 15 Oe~~[~~ (1200 A/m~~]~~).

TABLE X1.1 1120°C Sinter in Dissociated Ammonia

Sintered Density (g/cm^3)~~[~~ (kg/m^3~~]~~)		6.6 6600	6.9 6900	7.2 7200
~~[Relative] maximum permeability~~		~~1 700~~	~~2 100~~	~~2 700~~
(Relative) maximum permeability		1 700	2 100	2 700
Maximum flux density	(G)	9 000	10 500	12 000
	~~[T]~~	~~0.90~~	~~1.05~~	~~1.20~~
	(T)	0.90	1.05	1.20
Residual induction	(G)	7 800	9 000	10 500
	~~[T]~~	~~0.78~~	~~0.90~~	~~1.05~~
	(T)	0.78	0.90	1.05
Coercive field strength	(Oe)	2.1	2.1	2.1
	~~[A/m]~~	~~170~~	~~170~~	~~170~~
	(A/m)	170	170	170
0.2 % offset yield strength	(psi)	11 000	17 000	22 500
	~~[MPa]~~	~~76~~	~~120~~	~~155~~
	(MPa)	76	120	155
Ultimate tensile strength	(psi)	18 000	27 500	37 000
	~~[MPa]~~	~~120~~	~~190~~	~~260~~
	(MPa)	120	190	260
~~Percent elongation, 1 in. [25.4 mm]~~		~~6~~	~~11~~	~~16~~
Percent elongation, 1 in. (25.4 mm)		6	11	16
Apparent hardness	(HRF)	40	50	55

TABLE X1.2 1120°C Sinter in Dry Hydrogen or Vacuum

Sintered Density (g/cm³)~~[~~ (kg/m³~~]~~)		6.6 6600	6.9 6900	7.2 7200
~~[Relative] maximum permeability~~		~~1 800~~	~~2 300~~	~~2 900~~
(Relative) maximum permeability		1 800	2 300	2 900
Maximum flux density	(G)	9 500	10 500	12 000
	~~[T]~~	~~0.95~~	~~1.05~~	~~1.20~~
	(T)	0.95	1.05	1.20
Residual induction	(G)	8 200	9 700	11 000
	~~[T]~~	~~0.82~~	~~0.97~~	~~1.10~~
	(T)	0.82	0.97	1.10
Coercive field strength	(Oe)	1.8	1.8	1.8
	~~[A/m]~~	~~140~~	~~140~~	~~140~~
	(A/m)	140	140	140
0.2 % offset yield strength	(psi)	11 000	17 000	22 500
	~~[MPa]~~	~~76~~	~~120~~	~~155~~
	(MPa)	76	120	155
Ultimate tensile strength	(psi)	19 000	28 000	37 500
	~~[MPa]~~	~~130~~	~~190~~	~~259~~
	(MPa)	130	190	259
~~Percent elongation in 1 in. [25.4 mm]~~		~~8~~	~~12~~	~~17~~
Percent elongation in 1 in. (25.4 mm)		8	12	17
Apparent hardness	(HRF)	40	50	55

TABLE X1.3 1260°C Sinter in Dry Hydrogen or Vacuum

Sintered Density (g/cm³)~~[~~ (kg/m³~~]~~)		6.6 6600	6.9 6900	7.2 7200
~~[Relative] maximum permeability~~		~~2 800~~	~~3 300~~	~~3 800~~
(Relative) maximum permeability		2 800	3 300	3 800
Maximum flux density	(G)	10 000	11 500	13 000
	~~[T]~~	~~1.05~~	~~1.20~~	~~1.30~~
	(T)	1.05	1.20	1.30
Residual induction	(G)	8 500	10 000	11 500
	~~[T]~~	~~0.85~~	~~1.0~~	~~1.15~~
	(T)	0.85	1.0	1.15
Coercive field strength	(Oe)	1.6	1.6	1.6
	~~[A/m]~~	~~120~~	~~120~~	~~120~~
	(A/m)	120	120	120
0.2 % offset yield strength	(psi)	10 000	16 000	21 000
	~~[MPa]~~	~~69~~	~~110~~	~~140~~
	(MPa)	69	110	140
Ultimate tensile strength	(psi)	20 000	29 000	38 000
	~~[MPa]~~	~~140~~	~~200~~	~~260~~
	(MPa)	140	200	260
~~Percent elongation in 1 in. [25.4 mm]~~		~~10~~	~~15~~	~~20~~
Percent elongation in 1 in. (25.4 mm)		10	15	20
Apparent hardness	(HRF)	38	45	50