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Standard Specification for Iron-Phosphorus Powder Metallurgy ~~(P/M)~~ Parts for Soft Magnetic Applications[1]

This standard is issued under the fixed designation A839; 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-phosphorus powder metallurgy materials. These parts are used in magnetic applications requiring higher permeability and electrical resistivity and lower coercive field strength than attainable routinely from parts produced from iron powder.

1.2 Two powder types are covered; Type I containing nominally ~~0.45 %~~ 0.45 wt.% phosphorus, and Type II containing nominally ~~0.8 %~~ 0.8 wt.% phosphorus.

1.3 This specification deals with ~~P/M~~ powder metallurgy 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.

1.4 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.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A34/A34M Practice for Sampling and Procurement Testing of Magnetic Materials

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

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

~~B328~~B962 Test ~~Method for Density, Oil Content, and Interconnected Porosity of Sintered Metal Structural Parts and Oil-Impregnated Bearings~~Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle ~~(Withdrawn 2009)~~

E1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques

3. Ordering Information

3.1 Purchase orders for parts conforming to this specification shall include the following information:

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

3.1.2 The type of powder to be used (see 4.1 and Table 1).

3.1.3 Reference to an applicable part drawing.

3.1.4 Quantity required.

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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.

TABLE 1 Chemical Composition Requirements (in Weight Percent)

~~Element~~	~~Type I~~	~~Type II~~
~~Phosphorus~~	~~0.40/0.50~~	~~0.75/0.85~~
~~Carbon, max~~	~~0.03~~	~~0.03~~
~~Oxygen, max~~	~~0.10~~	~~0.10~~
~~Nitrogen, max~~	~~0.01~~	~~0.01~~
~~Iron[A]~~	~~balance~~	~~balance~~

TABLE 1 Chemical Composition Requirements (in Weight Percent)

Element	Type I	Type II
Phosphorus	0.40/0.50	0.75/0.85
Carbon, max	0.03	0.03
Oxygen, max	0.10	0.10
Nitrogen, max	0.01	0.01
Iron[A]	balance	balance

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

3.1.5 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 user and the producer (see 5.2).

3.1.6 Magnetic property requirements if they are other than stated in Table 2.

3.1.7 Whether certification of chemical analysis or magnetic property evaluation is required (see Sections 4 and 6).

3.1.8 Marking and packaging requirements (see Section 11).

3.1.9 Whether testing for magnetic aging is required.

3.1.10 Exceptions to this specification or special requirements such as functional testing, as mutually agreed upon between the producer and the user.

4. Chemical Composition

4.1 The chemical composition of the parts shall conform to the requirements prescribed in Table 1.

4.2 Chemical analysis for phosphorus shall be determined by wet chemistry in accordance with a method to be agreed upon between the user and the producer. Analysis of carbon, oxygen, and nitrogen shall be done in accordance with Test Methods E1019.

5. Sintered Density Requirements

5.1 Magnetic and residual induction of ~~P/M~~ powder metallurgy parts strongly depend on density. The density of ~~P/M~~ powder metallurgy parts is determined by the compressibility of the powder, the compacting pressure, and sintering practice (temperature, time, and atmosphere).

5.2 Parts produced in conformance with this specification shall have a minimum sintered density of 6.8 ~~g/cm~~Mg/m^3 ~~(6800 kg/m^3)~~ in the critical section of the part. The critical section shall be defined by agreement between the user and the producer.

5.3 Sintered density shall be determined in accordance with Test Method ~~B328~~B962.

6. Magnetic Property Requirements

6.1 Due to the nature of ~~P/M~~ powder metallurgy parts production, magnetic testing of each lot is not required by this specification. ~~However,~~Nevertheless, it is strongly recommended that the user require the producer to conduct periodic magnetic evaluations and to certify the results obtained. Such magnetic property evaluations shall be conducted in the following manner.

6.2 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 A34/A34M. The ring specimen(s) shall be produced from the same mixed lot of powder used to produce the parts.

6.3 The dc magnetic properties shall be determined in accordance with Test Methods A596/A596M or A773/A773M.

6.4 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)~~1200 A/m (15 Oe) needs to be determined. Other magnetic properties may be specified by mutual agreement between the user and the producer.

6.5 *Coercive Field Strength Requirements*—Three grades, defined by coercive field strength, are stipulated by this specification and are listed in Table 2. The coercive field strength requirements for Type I are based on an interlaboratory study conducted by ASTM Committee B09. The requirements for Type II are based on both interlaboratory study and technical literature.

TABLE 2 Maximum Coercive Field Strength Requirements

Grade	Powder Type I (0.45 % P)	Powder Type II (0.8 % P)
1	1.4 Oe (110 A/m)	1.2 Oe (96 A/m)
2	1.8 Oe (140 A/m)	1.4 Oe (110 A/m)
3	2.0 Oe (160 A/m)	1.7 Oe (140 A/m)

TABLE 2 Maximum Coercive Field Strength Requirements

Grade	Powder Type I (0.45 wt.% P)	Powder Type II (0.8 wt.% P)
1	110 A/m (1.4 Oe)	100 A/m (1.2 Oe)
2	140 A/m (1.8 Oe)	110 A/m (1.4 Oe)
3	160 A/m (2.0 Oe)	140 A/m (1.7 Oe)

TABLE X1.1 Typical Magnetic Properties

	Type I Powder (0.45 % P)			Type II Powder (0.8	
Sintered density, g/cm^3	6.8	7.0	7.2	6.8	7.0
(kg/m^3)	6 800	7 000	7 200	6 800	7 000
(Relative) maximum permeability	2 300	2 600	2 700	3 500	4 000
Maximum flux density, G	10 500	11 500	12 500	11 000	12 000
(T)	1.05	1.15	1.25	1.10	1.20
Residual induction, G	8 500	9 000	10 000	10 000	11 000
(T)	0.85	0.90	1.00	1.00	1.10
Coercive field strength, Oe	1.7	1.7	1.7	1.5	1.5
(A/m)	140	140	140	120	120

TABLE X1.2 Typical Mechanical Properties

	Type I Powder (0.45 % P)			Type II Powder (0.8	
Sintered density, g/cm^3	6.8	7.0	7.2	6.8	7.0
(kg/m^3)	6 800	7 000	7 200	6 800	7 000
0.2 % Offset yield strength, psi	30 000	32 000	35 000	40 000	45 000
(MPa)	210	220	240	280	310
Ultimate tensile strength, psi	40 000	45 000	50 000	48 000	50 000
(MPa)	280	310	340	330	340
Elongation in 1 in. (25.4 mm), %	5	7	7	2	3
Apparent hardness, HRB	40	45	55	55	65

TABLE X2.1 Typical Magnetic Properties

	Type I Powder (0.45 % P)			Type II Powder (0.8	
Sintered density, g/cm^3	7.0	7.2	7.4	7.0	7.2
(kg/m^3)	7 000	7 200	7 400	7 000	7 200
(Relative) maximum permeability	3 000	3 200	3 600	4 000	4 500
Maximum flux density, G	11 500	12 500	13 000	12 000	13 000
(T)	1.15	1.25	1.30	1.20	1.30
Residual induction, G	9 000	10 000	11 000	10 500	11 500
(T)	1.00	1.00	1.10	1.05	1.15
Coercive field strength, Oe	1.7	1.7	1.7	1.3	1.3
(A/m)	140	140	140	100	100

TABLE X2.2 Typical Mechanical Properties

	Type I Powder (0.45 % P)			Type II Powder (0.8	
Sintered density, g/cm^3	7.0	7.2	7.4	7.0	7.2
(kg/m^3)	7 000	7 200	7 400	7 000	7 200
0.2 % Offset yield strength, psi	32 000	35 000	38 000	45 000	48 000
(MPa)	220	240	260	310	330
Ultimate tensile strength, psi	45 000	50 000	55 000	53 000	57 000
(MPa)	310	340	380	360	390
Elongation in 1 in. (25.4 mm), %	7	7	7	4	4
Apparent hardness, HRB	45	55	60	65	70

TABLE X3.1 Typical Magnetic Properties

	Type I Powder (0.45 % P)			Type II Powder (0.8	
Sintered density, g/cm^3	7.0	7.2	7.4	7.0	7.2
(kg/m^3)	7 000	7 200	7 400	7 000	7 200
(Relative) maximum permeability	3 000	3 200	3 600	5 000	5 500
Maximum flux density, G	11 500	12 500	13 500	13 000	13 500
(T)	1.15	1.25	1.35	1.30	1.35
Residual induction, G	9 000	10 000	11 000	12 000	12 500
(T)	0.9	1.00	1.10	1.20	1.25
Coercive field strength, Oe	1.5	1.5	1.5	1.0	1.0
(A/m)	120	120	120	80	80

TABLE X3.2 Typical Mechanical Properties

	Type I Powder (0.45 % P)			Type II Powder (0.8	
Sintered density, g/cm^3	7.0	7.2	7.4	7.0	7.2
(kg/m^3)	7 000	7 200	7 400	7 000	7 200
0.2 % Offset yield strength, psi	32 000	39 000	41 000	45 000	48 000