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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 A 839; 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 % phosphorus, and Type II containing nominally 0.8 % phosphorus.

1.3 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.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 34/A 34M Practice for Sampling and Procurement Testing of Magnetic Materials

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

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

B 328 Test Method for Density, Oil Content, and Interconnected Porosity of Sintered Metal Structural Parts and Oil-Impregnated Bearings

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

## 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.

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 E 1019.

## 5. Sintered Density Requirements

5.1 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).

5.2 Parts produced in conformance with this specification shall have a minimum sintered density of 6.8 g/cm$^3$(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 B 328.

[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.

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**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.

**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) |

## 6. Magnetic Property Requirements

6.1 Due to 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 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 A 34/A 34M. 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 A 596/A 596M or A 773/A 773M.

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) 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 interlaboratory study conducted by ASTM Committee B09. The requirements for Type II are based on both interlaboratory study and technical literature.

6.6 *Magnetic Aging*—Nitrogen introduced during sintering can cause time-dependent degradation of magnetic properties. Therefore, when requested by the user, 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°C or 600 h at 100°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.

6.7 Since magnetic properties are strongly affected by process conditions, refer to the Appendix X1-Appendix X3 for typical values and explanatory notes.

## 7. Workmanship, Finish and Appearance

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

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

## 8. Sampling

8.1 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.

8.2 The user and the producer shall agree upon a representative number of specimens for testing.

## 9. Rejection and Rehearing

9.1 Parts that fail to conform to the requirements of this specification may 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.

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

## 10. Certification

10.1 When specified in the purchase order or contract, the user 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.

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

10.2.1 Chemical composition,

10.2.2 Part density in the critical section,

10.2.3 Magnetic test results, if required by the user, and

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

## 11. Packaging and Package Marking

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

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

## 12. Keywords

12.1 coercive field strength; iron-phosphorus; powder metallurgy (P/M); P/M parts



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## APPENDIXES

**(Nonmandatory Information)**

### X1. TYPICAL MAGNETIC AND MECHANICAL PROPERTIES SINTERED AT 1120°C IN DISSOCIATED AMMONIA

X1.1 The data provided in this appendix are for information only and are not requirements in this specification. Typical magnetic and mechanical properties are listed in Table X1.1 and Table X1.2, respectively. The influence of sintered density is shown in both tables. For Table X1.1, the 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 Typical Magnetic Properties**

| | Type I Powder (0.45 % P) | | | Type II Powder (0.8 % P) | | |
|---|---|---|---|---|---|---|
| Sintered density, g/cm $^3$ | 6.8 | 7.0 | 7.2 | 6.8 | 7.0 | 7.2 |
| (kg/m$^3$) | 6 800 | 7 000 | 7 200 | 6 800 | 7 000 | 7 200 |
| (Relative) maximum permeability | 2 300 | 2 600 | 2 700 | 3 500 | 4 000 | 4 500 |
| Maximum flux density, G | 10 500 | 11 500 | 12 500 | 11 000 | 12 000 | 13 000 |
| (T) | 1.05 | 1.15 | 1.25 | 1.10 | 1.20 | 1.30 |
| Residual induction, G | 8 500 | 9 000 | 10 000 | 10 000 | 11 000 | 12 000 |
| (T) | 0.85 | 0.90 | 1.00 | 1.00 | 1.10 | 1.20 |
| Coercive field strength, Oe | 1.7 | 1.7 | 1.7 | 1.5 | 1.5 | 1.5 |
| (A/m) | 140 | 140 | 140 | 120 | 120 | 120 |

**TABLE X1.2 Typical Mechanical Properties**

| | Type I Powder (0.45 % P) | | | Type II Powder (0.8 % P) | | |
|---|---|---|---|---|---|---|
| Sintered density, g/cm $^3$ | 6.8 | 7.0 | 7.2 | 6.8 | 7.0 | 7.2 |
| (kg/m$^3$) | 6 800 | 7 000 | 7 200 | 6 800 | 7 000 | 7 200 |
| 0.2 % Offset yield strength, psi | 30 000 | 32 000 | 35 000 | 40 000 | 45 000 | 50 000 |
| (MPa) | 210 | 220 | 240 | 280 | 310 | 340 |
| Ultimate tensile strength, psi | 40 000 | 45 000 | 50 000 | 48 000 | 50 000 | 55 000 |
| (MPa) | 280 | 310 | 340 | 330 | 340 | 380 |
| Elongation in 1 in. (25.4 mm), % | 5 | 7 | 7 | 2 | 3 | 3 |
| Apparent hardness, HRB | 40 | 45 | 55 | 55 | 65 | 70 |

### X2. TYPICAL MAGNETIC AND MECHANICAL PROPERTIES SINTERED AT 1120°C IN DRY HYDROGEN

X2.1 The data provided in this appendix are for information only and are not requirements in this specification. Typical magnetic and mechanical properties are listed in Table X2.1 and Table X2.2, respectively. The influence of sintered density is shown in both tables. For Table X2.1, the 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 X2.1 Typical Magnetic Properties**

| | Type I Powder (0.45 % P) | | | Type II Powder (0.8 % P) | | |
|---|---|---|---|---|---|---|
| Sintered density, g/cm$^3$ | 7.0 | 7.2 | 7.4 | 7.0 | 7.2 | 7.4 |
| (kg/m$^3$) | 7 000 | 7 200 | 7 400 | 7 000 | 7 200 | 7 400 |
| (Relative) maximum permeability | 3 000 | 3 200 | 3 600 | 4 000 | 4 500 | 5 000 |
| Maximum flux density, G | 11 500 | 12 500 | 13 000 | 12 000 | 13 000 | 13 500 |
| (T) | 1.15 | 1.25 | 1.30 | 1.20 | 1.30 | 1.35 |
| Residual induction, G | 9 000 | 10 000 | 11 000 | 10 500 | 11 500 | 13 000 |
| (T) | 1.00 | 1.00 | 1.10 | 1.05 | 1.15 | 1.30 |
| Coercive field strength, Oe | 1.7 | 1.7 | 1.7 | 1.3 | 1.3 | 1.3 |
| (A/m) | 140 | 140 | 140 | 100 | 100 | 100 |

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**TABLE X2.2 Typical Mechanical Properties**

| | Type I Powder (0.45 % P) | | | Type II Powder (0.8 % P) | | |
|---|---|---|---|---|---|---|
| Sintered density, g/cm$^3$ | 7.0 | 7.2 | 7.4 | 7.0 | 7.2 | 7.4 |
| (kg/m$^3$) | 7 000 | 7 200 | 7 400 | 7 000 | 7 200 | 7 400 |
| 0.2 % Offset yield strength, psi | 32 000 | 35 000 | 38 000 | 45 000 | 48 000 | 53 000 |
| (MPa) | 220 | 240 | 260 | 310 | 330 | 360 |
| Ultimate tensile strength, psi | 45 000 | 50 000 | 55 000 | 53 000 | 57 000 | 62 000 |
| (MPa) | 310 | 340 | 380 | 360 | 390 | 430 |
| Elongation in 1 in. (25.4 mm), % | 7 | 7 | 7 | 4 | 4 | 4 |
| Apparent hardness, HRB | 45 | 55 | 60 | 65 | 70 | 75 |

## X3. TYPICAL MAGNETIC AND MECHANICAL PROPERTIES SINTERED AT 1260°C IN DRY HYDROGEN

X3.1 The data provided in this appendix are for information only and are not requirements in this specification. Typical magnetic and mechanical properties are listed in Table X3.1 and Table X3.2, respectively. The influence of sintered density is shown in both tables. For Table X3.1, the 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 X3.1 Typical Magnetic Properties**

| | Type I Powder (0.45 % P) | | | Type II Powder (0.8 % P) | | |
|---|---|---|---|---|---|---|
| Sintered density, g/cm$^3$ | 7.0 | 7.2 | 7.4 | 7.0 | 7.2 | 7.4 |
| (kg/m$^3$) | 7 000 | 7 200 | 7 400 | 7 000 | 7 200 | 7 400 |
| (Relative) maximum permeability | 3 000 | 3 200 | 3 600 | 5 000 | 5 500 | 6 000 |
| Maximum flux density, G | 11 500 | 12 500 | 13 500 | 13 000 | 13 500 | 14 000 |
| (T) | 1.15 | 1.25 | 1.35 | 1.30 | 1.35 | 1.40 |
| Residual induction, G | 9 000 | 10 000 | 11 000 | 12 000 | 12 500 | 13 000 |
| (T) | 0.9 | 1.00 | 1.10 | 1.20 | 1.25 | 1.30 |
| Coercive field strength, Oe | 1.5 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 |
| (A/m) | 120 | 120 | 120 | 80 | 80 | 80 |

**TABLE X3.2 Typical Mechanical Properties**

| | Type I Powder (0.45 % P) | | | Type II Powder (0.8 % P) | | |
|---|---|---|---|---|---|---|
| Sintered density, g/cm$^3$ | 7.0 | 7.2 | 7.4 | 7.0 | 7.2 | 7.4 |
| (kg/m$^3$) | 7 000 | 7 200 | 7 400 | 7 000 | 7 200 | 7 400 |
| 0.2 % Offset yield strength, psi | 32 000 | 39 000 | 41 000 | 45 000 | 48 000 | 53 000 |
| (MPa) | 220 | 269 | 283 | 310 | 330 | 360 |
| Ultimate tensile strength, psi | 45 000 | 55 000 | 60 000 | 50 000 | 55 000 | 58 000 |
| (MPa) | 310 | 379 | 414 | 340 | 380 | 400 |
| Elongation in 1 in. (25.4 mm), % | 10 | 12 | 15 | 2 | 2 | 2 |
| Apparent hardness, HRB | 45 | 55 | 60 | 65 | 70 | 75 |

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