



Standard Test Method for Direct-Current Magnetic Properties of Materials Using the Ballistic Method and Ring Specimens¹

This standard is issued under the fixed designation A596/A596M; 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 test method covers dc ballistic testing for the determination of basic magnetic properties of materials in the form of ring, toroidal, link, double-lapped Epstein cores, or other standard shapes which may be cut, stamped, machined, or ground from cast, compacted, sintered, forged, or rolled materials. It includes tests for normal induction and hysteresis taken under conditions of steep wavefront reversals of the direct-current magnetic field strength.

1.2 This test method shall be used in conjunction with Practice [A34/A34M](#).

1.3 This test method is suitable for a testing range from very low magnetic field strength up to 200 or more Oe [15.9 or more kA/m]. The lower limit is determined by integrator sensitivity and the upper limit by heat generation in the magnetizing winding. Special techniques and short duration testing may extend the upper limit of magnetic field strength.

1.4 Testing under this test method is inherently more accurate than other methods. When specified dimensional or shape requirements are observed, the measurements are a good approximation to absolute properties. Test accuracy available is primarily limited by the accuracy of instrumentation. In most cases, equivalent results may be obtained using Test Method [A773/A773M](#) or the test methods of IEC Publication 60404-4.

1.5 This test method permits a choice of test specimen to permit measurement of properties in any desired direction relative to the direction of crystallographic orientation without interference from external yoke systems.

1.6 The symbols and abbreviated definitions used in this test method appear in [Fig. 1](#) and Sections [5](#), [6](#), [9](#), and [10](#). For the official definitions see Terminology [A340](#). Note that the term flux density used in this document is synonymous with the term magnetic induction.

¹ This test method is under the jurisdiction of ASTM Committee [A06](#) on Magnetic Properties and is the direct responsibility of Subcommittee [A06.01](#) on Test Methods.

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1.7 **Warning**—Mercury has been designated by EPA and many state agencies as a hazardous material that can cause central nervous system, kidney, and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury-containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website (<http://www.epa.gov/mercury/faq.htm>) for additional information. Users should be aware that selling mercury or mercury-containing products, or both, in your state may be prohibited by state law.

1.8 The values stated in either customary (cgs-emu and inch-pound) units or SI units are to be regarded separately as standard. Within this test method, the SI units are shown in brackets except for the sections concerning calculations where there are separate sections for the respective unit systems. The values stated in each system 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 method.

1.9 *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

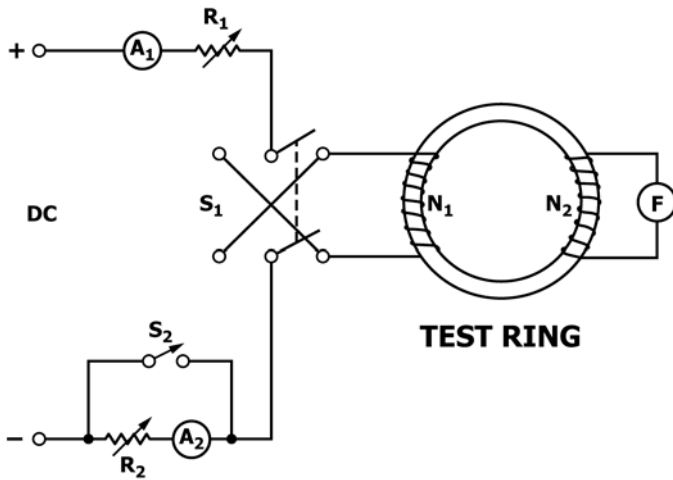
[A34/A34M Practice for Sampling and Procurement Testing of Magnetic Materials](#)

[A340 Terminology of Symbols and Definitions Relating to Magnetic Testing](#)

[A341/A341M Test Method for Direct Current Magnetic Properties of Materials Using D-C Permeameters and the Ballistic Test Methods](#)

[A343/A343M Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using](#)

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.



NOTE 1—

- A₁—Multirange ammeter, main-magnetizing current circuit
- A₂—Multirange ammeter, hysteresis-current circuit
- N₁—Magnetizing (primary) winding
- N₂—Flux-sensing (secondary) winding
- F—Electronic integrator
- R₁—Main current control rheostat
- R₂—Hysteresis current control rheostat
- S₁—Reversing switch
- S₂—Shunting switch for hysteresis current control rheostat

FIG. 1 Basic Circuit Using Ring-Type Cores

Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame

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

2.2 IEC Standard:³

Publication 60404-4 Ed. 2.2, Magnetic Materials—Part 4: Methods of Measurement of the D-C Magnetic Properties of Magnetically Soft Materials, IEC, 2008

3. Significance and Use

3.1 Test methods using suitable ring-type specimens⁴ are the preferred methods of determining the basic magnetic properties of a material caused by the absence of demagnetizing effects and are well suited for specification acceptance, service evaluation, and research and development.

3.2 Provided the test specimen is representative of the bulk material as is usually the case for thin strip and wire, this test is also suitable for design purposes.

3.3 When the test specimen is not necessarily representative of the bulk material such as a ring machined from a large forging or casting, the results of this test method may not be an accurate indicator of the magnetic properties of the bulk material. In such instances, the test results when viewed in

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

⁴ Lloyd, M. G., "Errors in Magnetic Testing with Ring Specimens," *Technical News Bulletin*, National Institute for Standards and Technology, Vol 5, 1909, p. 435 (S108).

context of past performance history will be useful for judging the suitability of the current material for the intended application.

4. Interferences

4.1 This test method has several important requirements. Unless adequate inside diameter to outside diameter ratios are maintained in the test specimens, the magnetic field strength will be excessively nonuniform throughout the test specimen and the measured parameters cannot be represented as material properties.

4.2 The basic quality of materials having directionally sensitive properties cannot be tested satisfactorily with rings or laminations. With them it is necessary to use Epstein specimens cut with their lengths in the direction of specific interest or to use long link-shaped or spirally wound toroidal core test specimens whose long dimensions are similarly located. The acceptable minimum width of strip used in such test specimens is also sensitive to the material under test. At present, it is believed that the grain-oriented silicon steels should have a strip width of at least 3 cm [30 mm].

4.3 Unless ring specimens are large in diameter, it is difficult to provide a sufficient number of primary turns needed to reach the highest magnetic field strength. In general, magnetic materials tend to have nonuniform properties throughout the body of the test specimen; for this reason, uniformly distributed test windings and uniform specimen cross-sectional area are highly desirable to suppress nonuniform behavior to a tolerable degree.

5. Apparatus

5.1 The apparatus shall consist of as many of the components described in 5.2 – 5.10 as are required to perform the desired test. The basic circuit is shown in Fig. 1.

5.2 Balance and Scales:

5.2.1 The balance used to weigh the test specimen shall be capable of weighing to an accuracy of better than ±0.1 % of the specimen mass.

5.2.2 The micrometer, caliper, or other length-measuring device used in the determination of magnetic path length and cross-sectional area shall be capable of measuring to an accuracy of better than ±0.1 % of the measured values.

5.3 dc Power Supply—The preferred source of dc current is a high quality linear power supply of either unipolar or bipolar operation. The power supply must exhibit high stability and very low ripple to achieve the most accurate results. Programmable bipolar operational amplifier power supplies have proven to be very satisfactory for this type of testing. Other stable sources of dc current such as storage batteries are permitted.

5.4 Main-Current-Control Rheostat R_J—When nonprogrammable sources of dc current such as storage batteries are used, rheostats must be used to control the current. These rheostats must have sufficient power rating and heat-dissipating capability to handle the largest test current without undesirable changes in resistance and, therefore, magnetizing current during conduct of the test.

5.5 Hysteresis-Current-Control Rheostat R_2 —The hysteresis-current-control rheostat, when required, must have the same power rating and resistance as the main-current-control rheostat.

5.6 Main-Current Ammeter A_1 —Measurement of the magnetizing current can be accomplished with either a dc ammeter or a combination of a precision shunt resistor and dc voltmeter. The meters and shunt resistor, if used, must have an accuracy of at least 0.25 %. To improve test accuracy multirange digital ammeters or voltmeters are preferred. Autoranging capability is desirable for convenience but is not essential for this test method. If analog meters are used, the ranges must be such that all test readings are made in the upper two thirds of the scale.

5.7 Hysteresis-Current Ammeter, A_2 —The hysteresis-current measuring system shall conform to the requirements in 5.6. In general, a separate measuring system is not required since the main current ammeter (A_1) can also be used to measure the hysteresis current.

5.8 Reversing Switch, S_1 —Because of the low resistance nature of the magnetizing circuit, it is imperative that high quality switches be used. Changes in switch resistance upon reversal will cause deviation from the cyclically magnetized condition which, if excessive, will impair test accuracy and precision. Experience has shown that mercury switches are the best suited for this application. Knife blade switches or mechanical or electrically operated contactors can also be used provided the requirement for uniform and equal contact resistance can be maintained. Because of the presence of leakage currents in the open condition, solid state relays are not permitted. The difficulties inherent in the use of main current reversing switches can be minimized by use of linear power supplies capable of accepting a remote programming signal. Such power supplies are permitted provided that the magnetizing current is equal (to within 0.1 %) in either polarity when normal induction testing is conducted, current reversals can be conducted with no overshoot or oscillation and the magnetizing current is truly zero for the zero current programming signal.

5.9 Hysteresis Switch, S_2 (When Required)—This switch should conform to requirements in 5.8.

5.10 Integrator, F —Because of their superior accuracy, stability, and ease of operation, electronic charge integrators are the preferred means of measuring magnetic flux. Integrators using either operational amplifier and capacitor feedback (analog integrator) or pulse counting are permitted. The accuracy of the integrator must be better than 1 % full scale. If analog display meters are used to read the value of flux, the measurement should be made on the upper two thirds of the scale. Analog integrators must have drift adjust circuitry and the drift should not exceed 100 Maxwell-turns [10^{-6} Wb-turns] per minute on the most sensitive range. It is also desirable that the integrator have appropriate scaling circuitry to permit direct reading of either flux (ϕ) or flux density (B).

6. Test Specimen

6.1 When the test specimen represents a test lot of material, its selection shall conform to the requirements of Practice [A34/A34M](#) or of an individual specification.

6.2 To qualify as a test specimen suitable for evaluation of material properties the effective ratio of mean diameter to radial width shall be not less than 10 to 1 (or an inside diameter to outside diameter ratio not less than 0.82). When the test specimen has smaller ratios than the above requirements, the test results should not be represented as material properties but should be called core properties because of nonuniform flux distribution.

6.3 When link, oval-shaped, or rectangular test specimen forms are used, the requirements of 6.2 apply to the end or corner sections where flux crowding occurs. When straight-sided test specimens are very long relative to the length of the corner or end sections, they are suitable for basic material properties evaluation with relatively unoriented materials provided the uncertainty in determination of true-path (effective) length is less than 5 % of the total path length. When this uncertainty in path length (shortest or longest relative to the mean-path length) exceeds 5 %, the test values should be reported as core properties and not basic material properties.

6.4 The test specimen may be constructed of solid, laminated, or strip materials and in any of the shapes described in 1.1.

6.5 Test specimen cores made from strip may be laminated, machined, spirally wound, or Epstein specimens (the method of selection for Epstein specimens is described in Test Method [A343/A343M](#), Annex A3). When the material is to be tested half transverse and half longitudinal, the material shall be cut into Epstein strips or square laminations of adequate dimensional ratio.

6.6 Test specimens used for basic material evaluation shall be cut, machined, ground, slit, or otherwise formed to have a cross section that remains sufficiently uniform that its nonuniformity will not materially affect the accuracy of establishing and measuring flux density, B , or magnetic field strength, H , in the test specimen.

6.7 When required for material properties development, the test specimen shall have received a stress relief or other heat treatment after preparation. This heat treatment is subject to agreement between manufacturer and purchaser, manufacturer's recommendation, or the recommended heat treatment provided by the appropriate ASTM standard for the material. The heat treatment used shall be reported with the magnetic test results.

7. Calibration of Integrator

7.1 Practical operating experience has shown that provided a proper warmup period is allowed, electronic integrators require infrequent calibration. Calibration is not an integral part of this test method. When calibration is required, it can be accomplished with either a mutual inductor or a volt-second source. Because of their traceability to the fundamental units of voltage and time, volt-second sources are the preferred means of calibration. The accuracy of either the mutual inductor or volt-second source must be better than the rated full-scale accuracy of the integrator.