INTERNATIONAL

Designation: A 894/A 894M – 00

Standard Test Method for Saturation Magnetization or Induction of Nonmetallic Magnetic Materials[1]

This standard is issued under the fixed designation A 894/A 894M; 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 the measurement of saturation magnetization of magnetic materials using a vibrating sample magnetometer.

1.2 Explanation of symbols and abbreviated definitions appear in the text of this test method. The official symbols and definitions are listed in Terminology A 340.

1.3 The values stated in either customary (absolute (or practical) cgs-emu) units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. 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.

1.4 *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:*

A 340 Terminology of Symbols and Defniitions Relating to Magnetic Testing[2]

3. Summary of Test Method

3.1 The magnetic induction B, magnetic field strength H, and magnetization M in a material are related by the following equation (**1**):[3]

$$B = H + 4\pi M \qquad \text{(cgs units)}$$

$$B = \mu_o(H + M) \qquad \text{[SI units]}$$

3.1.1 In this test method, cgs units are given in parentheses ( ) and SI units in square brackets [ ].

3.2 The magnetization M is the magnetic moment per unit volume of material. In a ferromagnetic or ferrimagnetic material, M increases with the applied magnetic field H, but at sufficiently high values of H, M approaches a constant maximum value called the *saturation magnetization* M_s (emu/cm^3) or [A/m]. The corresponding value of $B - H = 4\pi M_s$(gauss) or $B - \mu_o H = \mu_o M_s$[tesla] is called the *saturation induction*. It is sometimes given the label B_s.

3.3 If a sphere of isotropic magnetic material is placed in a uniform magnetic field, the sphere becomes uniformly magnetized in a direction parallel to the applied field. The magnetic field in the space outside the sphere is exactly that of a magnetic dipole located at the center of the sphere and oriented parallel to the magnetization of the sphere. The strength of this magnetic dipole is equal to the total magnetic moment of the sphere, which is given by

$$m = Mv \text{ (emu) or } [\text{A}\cdot\text{m}^2]$$

where:

v = is the volume of the sphere, (cm^3) or [m^3].

Section 4 describes an apparatus that provides an indication or reading proportional to the strength of this dipole field and therefore proportional to the magnetization M of the sample. If the proportionality constant between this reading and the magnetic moment can be established, and if the volume of the sample is known, the magnetization of the sample is determined. Then if the sample can be shown to be magnetically saturated, the *saturation magnetization* is determined.

4. Apparatus

4.1 The equipment used for the measurement is called a *vibrating sample magnetometer* (**2**) and is illustrated schematically in Fig. 1. The sample is attached to the end of a nonmagnetic, nonconducting rod, and placed in a uniform transverse magnetic field generated by an electromagnet or solenoid. The sample and rod are oscillated or vibrated in a direction perpendicular to the field. This oscillating drive may be produced by attaching the end of the sample rod to a loudspeaker cone or a similar electromagnetic oscillator and

[1] This test method is under the jurisdiction of ASTM Committee A-6 on Magnetic Properties and is the direct responsibility of A06.01 on Test Methods.

Current edition approved Oct. 10, 2000. Published December 2000. Last previous edition A 894 – 95. (Formerly F 133 – 70 (1981)).

[2] *Annual Book of ASTM Standards*, Vol 03.04.

[3] The boldface numbers in parentheses refer to a list of references at the back of this standard.

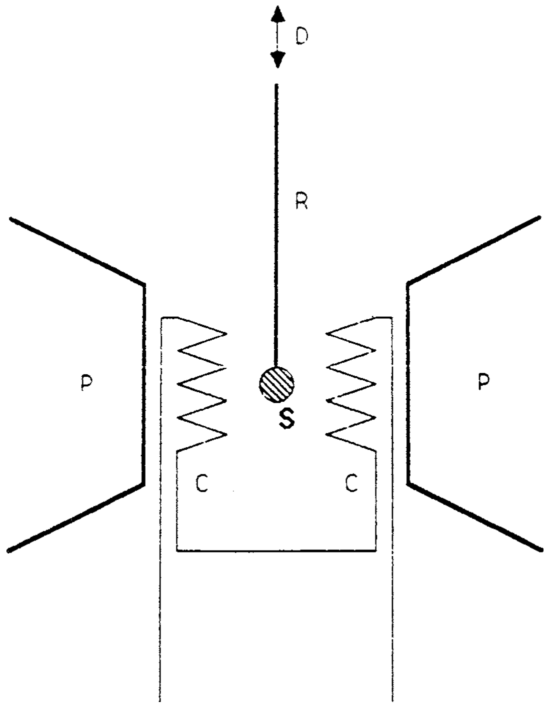

FIG. 1 ***S*, Sample; *R*, Mounting Rod; *D*, Oscillating Drive Mechanism; *P*, Magnet Pole Pieces; *C*, Measuring Coils**

driving the loudspeaker coil with an appropriate ac current. Alternatively, the rod may be oscillated by a mechanical crank or cam driven by a small motor. The frequency and amplitude of the oscillation must be held constant, either by the mechanical design of the apparatus or by an appropriate feedback system. The operating frequency is usually chosen in the range 30 to 100 Hz, and the amplitude is usually chosen to be 0.01 to 0.1 cm [0.1 to 1 mm]. The operating frequency should not be an integer multiple of the power frequency to avoid pickup of spurious signals.

4.1.1 One or more coils are placed symmetrically with respect to the sample, oriented so that the moving dipole field of the sample produces a changing magnetic flux in the coils. The resulting ac voltage in the coils is amplified and measured and is proportional to the dipole moment of the sample and therefore to the magnetization of the sample.

4.1.2 Various coil orientations are possible. In general, the coil positions and coil connections are chosen to cancel the effects of any time-varying fields other than those caused by the oscillation of the sample. For a discussion of the design and placement of these coils, see Refs **3** and **4**. The coils typically contain hundreds or thousands of turns to increase the amplitude of the induced voltage. The signal may be amplified by a tuned amplifier whose gain is maximum at the frequency of oscillation, or preferably by a lock-in amplifier operated at the oscillation frequency. The coils may be connected in series or as parallel inputs to a differential amplifier; the latter has some practical advantages. The output of the tuned amplifier will be an ac voltage, while the output of the lock-in amplifier will be a dc voltage.

4.1.3 If a superconducting solenoid is used to provide the magnetic field, it is usually most convenient to have the direction of sample vibration parallel rather than perpendicular to the field. The operation of the instrument is basically unchanged, and all the provisions of this standard apply to both cases.

4.2 One version of the vibrating sample magnetometer uses a second set of coils placed outside the magnetizing field and a standard sample comprising a small permanent magnet attached to the sample rod (see Fig. 2). In this case, the signal from the permanent magnet can be balanced against the signal from the sample, so that the apparatus is operated in a null mode. Alternatively, the output from the second set of coils may simply be used to monitor or control the amplitude of the sample vibration. A variable gap capacitor, with one plate fixed and one attached to the sample rod, can be used to control the amplitude of vibration in place of a second set of coils plus a magnet.

4.3 An advantage of the vibrating sample magnetometer is that the sample temperature may be easily raised or lowered with simple heaters or refrigerators. Some precautions are necessary in this case, but they are not a part of this standard.

4.4 Vibrating sample magnetometers are commercially available from several manufacturers in various countries, or can be constructed with normal machine shop facilities.

5. Test Specimen

5.1 The test specimen shall preferably be in the form of an isotropic sphere. The size of the sphere will depend on the

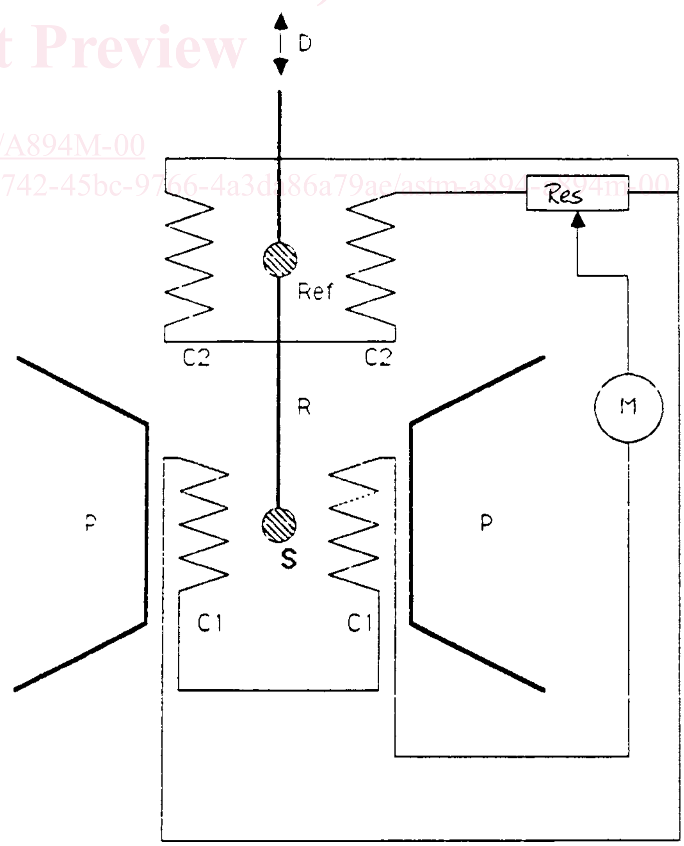

FIG. 2 ***Ref*, Reference Standard (Permanent Magnet); C_1, C_2, Measuring Coils; *M*, Null-Indicating Meter; *Res*, Calibrated Variable Resistor. Other Parts as in Fig. 1.**