Designation: A804/A804M – 04

Standard Test Methods for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Sheet-Type Test Specimens[1]

This standard is issued under the fixed designation A804/A804M; 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 These test methods cover the determination of specific core loss and peak permeability of single layers of sheet-type specimens tested with normal excitation at a frequency of 50 or 60 Hz.

NOTE 1—These test methods have been applied only at the commercial power frequencies, 50 and 60 Hz, but with proper instrumentation and application of the principles of testing and calibration embodied in the test methods, they are believed to be adaptable to testing at frequencies ranging from 25 to 400 Hz.

1.2 These test methods use calibration procedures that provide correlation with the 25-cm [250-mm] Epstein test.

1.3 The range of test magnetic flux densities is governed by the properties of the test specimen and by the available instruments and other equipment components. Normally, nonoriented electrical steels can be tested over a range from 8 to 16 kG [0.8 to 1.6 T] for core loss. For oriented electrical steels, the normal range extends to 18 kG [1.8 T]. Maximum magnetic flux densities in peak permeability testing are limited principally by heating of the magnetizing winding and tests are limited normally to a maximum ac magnetic field strength of about 150 Oe [12 000 A/m].

1.4 These test methods cover two alternative procedures as follows:

Test Method 1—Sections 6-12
Test Method 2—Sections 13-19

1.4.1 Test Method 1 uses a test fixture having (*1*) two windings that encircle the test specimen, and (*2*) a ferromagnetic yoke structure that serves as the flux return path and has low core loss and low magnetic reluctance.

1.4.2 Test Method 2 uses a test fixture having (*1*) two windings that encircle the test specimen, (*2*) a third winding located inside the other two windings and immediately adjacent to one surface of the test specimen, and (*3*) a ferromagnetic yoke structure which serves as the flux-return path and has low magnetic reluctance.

1.5 The values and equations stated in customary (cgs-emu and inch-pound) units or SI units are to be regarded separately as standard. Within this standard, 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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this standard.

1.6 *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
A343/A343M Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame
A677 Specification for Nonoriented Electrical Steel Fully Processed Types
A683/A683M Specification for Nonoriented Electrical Steel, Semiprocessed Types
A876 Specification for Flat-Rolled, Grain-Oriented, Silicon-Iron, Electrical Steel, Fully Processed Types

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—The definitions of terms, symbols, and conversion factors relating to magnetic testing found in Definitions A340 are used in these methods.

3.2 *Definitions of Terms Specific to This Standard:*

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[1] These methods are under the jurisdiction of ASTM Committee A06 on Magnetic Properties and are the direct responsibility of Subcommittee A06.01 on Test Methods.

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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.

3.2.1 *sheet specimen*—a rectangular specimen comprised of a single piece of material or paralleled multiple strips of material arranged in a single layer.

4. Significance and Use

4.1 *Materials Evaluation*—These test methods were developed to supplement the testing of Epstein specimens for applications involving the use of flat, sheared laminations where the testing of Epstein specimens in either the as-sheared or stress-relief-annealed condition fails to provide the most satisfactory method of predicting magnetic performance in the application. As a principal example, the methods have been found particularly applicable to the control and evaluation of the magnetic properties of thermally flattened, grain-oriented electrical steel (Condition F5, Specification A876) used as lamination stock for cores of power transformers. Inasmuch as the methods can only be reliably used to determine unidirectional magnetic properties, the methods have limited applicability to the testing of fully processed nonoriented electrical steels as normally practiced (Specification A677).

4.2 *Specification Acceptance*—The reproducibility of test results and the accuracy relative to the 25-cm [250-mm] Epstein method of test are considered such as to render the methods suitable for materials specification testing.

4.3 *Interpretation of Test Results*—Because of specimen size, considerable variation in magnetic properties may be present within a single specimen or between specimens that may be combined for testing purposes. Also, variations may exist in test values that are combined to represent a test lot of material. Test results reported will therefore, in general, represent averages of magnetic quality and in certain applications, particularly those involving narrow widths of laminations, deviations in magnetic performance from those expected from reported data may occur at times. Additionally, application of test data to the design or evaluation of a particular magnetic device must recognize the influence of magnetic circuitry upon performance and the possible deterioration in magnetic properties arising from construction of the device.

4.4 *Recommended Standard Tests*—These methods have been principally applied to the magnetic testing of thermally flattened, grain-oriented electrical steels at 50 and 60 Hz. Specific core loss at 15 or 17 kG [1.5 or 1.7 T] and peak permeability (if required) at 10 Oe [796 A/m] are the recommended parameters for evaluating this class of material.

5. Sampling

5.1 *Lot Size and Sampling*—Unless otherwise established by mutual agreement between the manufacturer and the purchaser, determination of a lot size and the sampling of a lot to obtain sheets for specimen preparation shall follow the recommendations of Practice A34/A34M, Sections 4 and 5.

METHOD 1 TWO-WINDING YOKE-FIXTURE TEST METHOD

6. Basic Test Circuit

6.1 Fig. 1 provides a schematic circuit diagram for the test method. A power source of precisely controllable ac sinusoidal voltage is used to energize the primary circuit. To minimize flux-waveform distortion, current ratings of the power source and of the wiring and switches in the primary circuit shall be such as to provide very low impedance relative to the impedance arising from the test fixture and test specimen. Ratings of switches and wiring in the secondary circuit also shall be such as to cause negligible voltage drop between the terminals of the secondary test winding and the terminals of the measuring instruments.

7. Apparatus

7.1 The test circuit shall incorporate as many of the following components as are required to perform the desired measurements.

7.2 *Yoke Test Fixture*—Fig. 2 and Fig. 3 show line drawings of a single-yoke fixture and a double-yoke fixture, respectively. A double-yoke fixture is preferred in this method but a single-yoke fixture is permitted. Directions concerning the design, construction, and calibration of the fixture are given in 7.2.1, 7.2.2, Annex A1, and Annex A2.

7.2.1 *Yoke Structure*—Various dimensions and fabrication procedures in construction are permissible. Since the recommended calibration procedure provides correlation with the

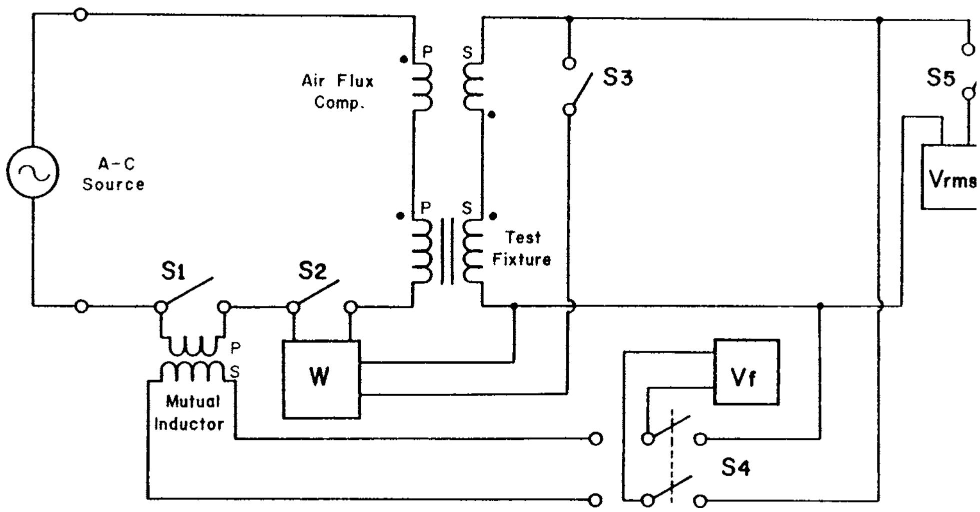

FIG. 1 Basic Circuit Diagram for Method 1

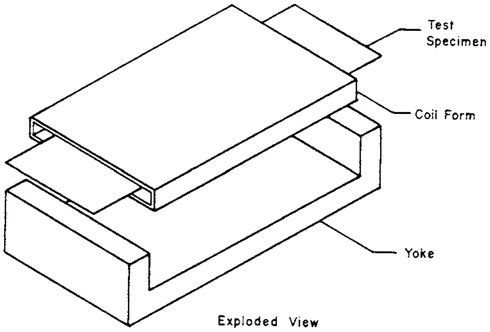

FIG. 2 Single-Yoke Fixture (Exploded View)

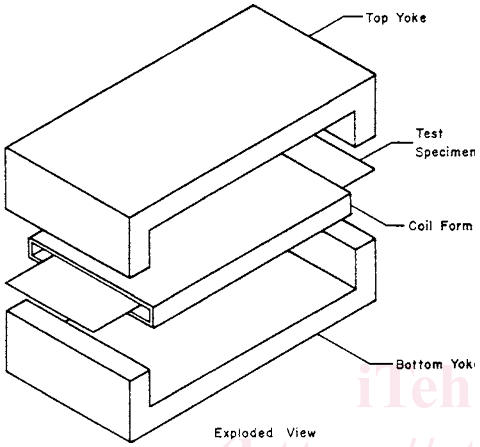

FIG. 3 Double-Yoke Fixture (Exploded View)

25-cm [250-mm] Epstein test, the minimum inside dimension between pole faces must be at least 22 cm [220 mm]. The thickness of the pole faces should be not less than 2.5 cm [25 mm]. It is recognized that pole faces as narrow as 1.9 cm [19 mm] are being used with nickel-iron yoke systems with good results. To minimize the influences of coil-end and pole-face effects, the yokes should be longer than the recommended minimum. For calibration purposes, it is suggested that the width of the fixture be such as to accommodate a specimen of at least 36-cm [360-mm] width which corresponds to the combined width of twelve Epstein-type specimens. Should the fixture width be less than 36 cm [360 mm], it will be necessary to test each calibration specimen in two parts and average the results.

7.2.2 *Test Windings*—The test windings, which shall consist of a primary (exciting) winding and a secondary (potential) winding, shall be uniformly and closely wound on a nonmagnetic, nonconducting coil form and each shall span the greatest practicable distance between the pole faces of the yoke fixture. It is recommended that the number of turns in the primary and secondary windings be equal. The number of turns may be chosen to suit the instrumentation, mass of specimen and test frequency. The secondary winding shall be the innermost winding and, with instrumentation of suitably high input resistance, normally may consist of a single layer. To reduce self-impedance and thereby minimize flux-waveform distortion, it is recommended that the primary winding consist of multiple layers of equal turns connected in parallel. The number of such layers should be optimized based on consideration of a reduction in winding resistance versus an increase in inductive reactance at the third harmonic of the principal test frequency used. The primary and secondary turns shall be wound in the same direction from a common starting point at one end of the coil form. Also, to minimize self-impedances of the windings, the opening in the coil form should be no greater than required to allow easy insertion of the test specimen. Construction and mounting of the test coil assembly must be such that the test specimen will be maintained without mechanical distortion in the plane established by the pole faces of the yoke(s) of the test fixture.

7.3 *Air-Flux Compensator*—To provide a means of determining intrinsic induction in the test specimen, an air-core mutual inductor shall constitute part of the test-coil system. The respective primary and secondary windings of the air-core inductor and the test-specimen coil shall be connected in series and the voltage polarities of the secondary windings shall be in opposition. By proper adjustment of the mutual inductance of the air-core inductor, the average of the voltage developed across the combined secondary windings is proportional to the intrinsic induction in the test specimen. Directions for construction and adjustment of the air-core mutual inductor for air-flux compensation are found in Annex A3.

7.4 *Flux Voltmeter, V_f*—A full-wave, true-average voltmeter, with scale reading in average voltage times 1.111 so that its indications will be identical with those of a true rms voltmeter on a pure sinusoidal voltage, shall be provided for evaluating the peak value of the test magnetic flux density. To produce the estimated precision of test under this method, the full-scale meter errors shall not exceed 0.25 % (Note 2). Meters of 0.5 % or more error may be used at reduced accuracy. Either digital or analog flux voltmeters are permitted. The normally high input impedance of digital voltmeters is desirable to minimize loading effects and to reduce the magnitude of instrument loss compensations. The input resistance of an analog flux voltmeter shall not be less than 1000 Ω/V of full-scale indication. A resistive voltage divider, a standard-ratio transformer, or other variable scaling device may be used to cause the flux voltmeter to indicate directly in units of magnetic flux density if the combination of basic instrument and scaling device conforms to the specifications stated above.

NOTE 2—Inaccuracies in setting the test voltage produce percentage errors approximately two times as large in the specific core loss. Care should also be taken to avoid errors caused by temperature and frequency effects in the instrument.

7.4.1 If used with a mutual inductor as a peak ammeter at magnetic flux densities well above the knee of the magnetization curve, the flux voltmeter must be capable of accurately measuring the extremely nonsinusoidal (peaked) voltage that is induced in the secondary winding of the mutual inductor. Additionally, if so used, an analog flux voltmeter should have an input resistance of 5000 to 10 000 Ω/V of full-scale indication.

7.5 *RMS Voltmeter, V_{rms}*—A true rms-indicating voltmeter shall be provided for evaluating the form factor of the voltage induced in the secondary winding of the test fixture and for evaluating the instrument losses. The accuracy of the rms voltmeter shall be the same as that specified for the flux voltmeter. Either digital or analog rms voltmeters are permitted. The normally high input impedance of digital voltmeters is desirable to minimize loading effects and to reduce the magnitude of instrument loss compensations. The input resistance of an analog rms voltmeter shall not be less than 500 Ω/V of full-scale indication.

7.6 *Wattmeter, W*—The full-scale accuracy of the wattmeter must be better than ±0.25 % at the frequency of test and at unity power factor. The power factor encountered by a wattmeter during a core loss test on a specimen is always less than unity and, at magnetic flux densities far above the knee of the magnetization curve, approaches zero. The wattmeter must maintain adequate accuracy (better than ±1 % of reading) even at the most severe (lowest) power factor that is presented to it. Variable scaling devices may be used to cause the wattmeter to indicate directly in units of specific core loss if the combination of basic instrument and scaling devices conforms to the specifications stated here.

7.6.1 *Electrodynamometer Wattmeter*—A reflecting-type dynamometer is recommended among this class of instruments, but, if the specimen mass is sufficiently large, a direct-indicating electrodynamometer wattmeter of the highest available sensitivity and lowest power-factor capability may be used.

7.6.1.1 The sensitivity of the electrodynamometer wattmeter must be such that the connection of the potential circuit of the wattmeter, during testing, to the secondary winding of the test fixture does not change the terminal voltage of the secondary by more than 0.05 %. Also, the resistance of the potential circuit of the wattmeter must be sufficiently high that the inductive reactance of the potential coil of the wattmeter in combination with the leakage reactance of the secondary circuit of the test fixture does not result in appreciable defect angle errors in the measurements. Should the impedance of this combined reactance at the test frequency exceed 1 Ω per 1000 Ω of resistance in the wattmeter-potential circuit, the potential circuit must be compensated for this reactance.

7.6.1.2 The impedance of the current coil of the electrodynamometer wattmeter should not exceed 1 Ω. If flux waveform distortion otherwise tends to be excessive, this impedance should be not more than 0.1 Ω. The rated current-carrying capacity of the current coil must be compatible with the maximum rms primary current to be encountered during core-loss testing. Preferably the current-carrying capacity should be at least 10 rms amperes.

7.6.2 *Electronic Digital Wattmeter*—Electronic digital wattmeters have been developed that have proven satisfactory for use under the provisions of this test method. Usage of a suitable electronic digital wattmeter is permitted as an alternative to an electrodynamometer wattmeter in this test method. An electronic digital wattmeter oftentimes is preferred in this test method because of its digital readout and its capability for direct interfacing with electronic data acquisition systems.

7.6.2.1 The voltage input circuitry of the electronic digital wattmeter must have an input impedance sufficiently high that connection of the circuitry, during testing, to the secondary winding of the test fixture does not change the terminal voltage of the secondary by more than 0.05 %. Also the voltage input circuitry must be capable of accepting the maximum peak voltage that is induced in the secondary winding during testing.

7.6.2.2 The current input circuitry of the electronic digital wattmeter must have an input impedance of no more than 1 Ω. Preferably the input impedance should be no more than 0.1 Ω if the flux waveform distortion otherwise tends to be excessive. Also the current input circuitry must be capable of accepting the maximum rms current and the maximum peak current drawn by the primary winding of the test fixture when core loss tests are being performed. In particular, since the primary current will be very nonsinusoidal (peaked) if core-loss tests are performed on a specimen at magnetic flux densities above the knee of the magnetization curve, the crest factor capability of the current input circuitry should be three or more.

7.7 *Devices for Peak-Current Measurement*—A means of determining the peak value of the exciting current is required if an evaluation of peak permeability is to be made by the peak-current method.

7.7.1 An air-core mutual inductor and a flux voltmeter comprise the apparatus most frequently used to measure peak exciting current. Use of this apparatus is based on the same theoretical considerations that indicate the use of a flux voltmeter on the secondary of the test fixture to measure the peak magnetic flux density; namely, that when a flux voltmeter is connected to a test coil, the flux voltmeter indications are proportional to the peak value of the flux linking the coil. In the case of an air-core mutual inductor, the peak value of flux (and hence the indications of the flux voltmeter connected to its secondary winding) will be proportional to the peak value of its primary current. A mutual inductor used for this purpose must have reasonably low primary impedance so that its insertion will not materially affect the primary circuit conditions and yet must have sufficiently high mutual inductance to provide a satisfactorily high voltage to the flux voltmeter for primary currents corresponding to the desired range in peak magnetic field strength. The mutual inductor secondary impedance should be low if any significant secondary current is drawn by a low impedance flux voltmeter. The addition of the flux voltmeter should not change the mutual inductor secondary terminal voltage by more than 0.25 %. It is important that the mutual inductor be located in the test equipment in such a position that its windings will not be linked by ac leakage flux from other apparatus. Care should be taken to avoid locating it so close to any magnetic material or any conducting material that its calibration and linearity might be affected. Directions for construction and calibration of the mutual inductor for peak-current measurement are given in Annex A4.

7.7.2 *Peak-to-Peak Ammeter*—Even at commercial power frequencies, there can be appreciable error in the measurement of peak exciting current if winding capacitances and inductances and flux voltmeter errors begin to become important at some of the high-harmonic frequencies occasioned by the extremely nonsinusoidal character of the voltage waveform induced in the secondary of the mutual inductor by the nonsinusoidal exciting-current waveform. In such cases, the peak-current measurement may be made with a voltmeter whose indications are proportional to the peak-to-peak value of the voltage drop across a low value of standard resistance connected in series with the primary winding of the test fixture. This peak-to-peak-reading voltmeter should have a nominal full-scale accuracy of better than ±3 % at the test frequency and be able to accommodate voltages with a crest factor of up to approximately 5. Care must be exercised that the standard resistor (usually in the range from 0.1 to 1.0 Ω) carrying the exciting current has adequate current-carrying capacity and is accurate to at least 0.1 % in value. It must have negligible temperature and frequency dependence under the conditions applying in this method. If desired, the value of the resistor may be such that the peak-reading voltmeter indicates directly in terms of peak magnetic field strength provided that the resistor conforms to the limitations stated previously. Normally this resistor will replace the mutual inductor in the circuit of Fig. 1 and the shorting switch, S_1, is used to remove this extra resistance from the primary circuit when not in use.

7.8 *Power Supply*—A precisely controllable source of sinusoidal test voltage with sufficient current and voltage capability, low internal impedance, and excellent stability is mandatory. Voltage amplitude and frequency stability should be maintained within ±0.1 %. Electronic power sources using negative feedback from the secondary winding of the test fixture to reduce flux waveform distortion have been found to perform quite satisfactorily in this test method.

8. Specimen Preparation

8.1 The type of test fixture and its dimensions govern the dimensions of permissible test specimens. The minimum length of a specimen shall be no less than the outside dimension of the distance between pole faces of the test fixture. With a double-yoke fixture, the amount of projection of the specimen beyond the pole faces is not critical but should be no longer than necessary for convenient loading and unloading of the specimen. For a single-yoke fixture, the length of the specimen must equal the length of the specimens used in calibration of the fixture. This length preferably is the minimum permissible length. For maximum accuracy, the specimen width should, as nearly as practicable, be the maximum that can be accommodated by the opening of the test coil. As a minimum, it is recommended that the specimen width be at least one half of the maximum width that can be accommodated by the test coil.

8.2 The specimens shall be sheared as rectangular as practicable to a length tolerance not exceeding ±0.1 %. Excessive burr and mechanical distortion are to be avoided in the shearing operation. For tests of grain-oriented electrical steel parallel to the direction of rolling, the angular deviation of the specimen length axis from the rolling direction shall not exceed 1.0°.

8.3 Where it is desirable to minimize the effects of slitting or shearing strains on the magnetic properties of an as-sheared test specimen, minimum width shall not be less than 100 mm.

8.4 Unless otherwise agreed upon between the producer and the user, it is recommended that sufficient specimens be prepared so as to represent substantially the entire width of the sheet samples taken from a test lot. If such samples are of less than optimum width (see 8.1), the samples should be of sufficient length that consecutive specimens may be prepared for testing in a paralleled, single-layer configuration.

9. Procedure

9.1 *Initial Determinations*—Before testing, check length of each specimen for conformity within ±0.1 % of the desired length. Discard specimens showing evidence of mechanical abuse. Weigh and record the mass of each specimen to an accuracy of ±0.1 %.

9.2 *Specimen Loading*—When loaded into the test fixture, the test specimen must be centered on the longitudinal and transverse axes of the test coil. When using a single-yoke fixture, sufficient pressure from nonmagnetic weights shall be used to bring the specimen into close contact with the pole faces of the yoke.

9.3 *Demagnetization*—The specimen should be demagnetized before measurements of any magnetic property are made. With the required apparatus connected as shown in Fig. 1 and with switches S_1 and S_2 closed, S_4 closed to the test fixture side, and S_3 and S_5 open, accomplish this demagnetization by initially applying a voltage from the power source to the primary circuit that is sufficient to magnetize the specimen to a magnetic flux density above the knee of its magnetization curve (magnetic flux density may be determined from the reading of the flux voltmeter by means of the equation of 10.1 or the equation of 11.1) and then decrease the voltage slowly and smoothly (or in small steps) to a very low magnetic flux density. After this demagnetization, test promptly for the desired test points. When multiple test points are required, perform the test in order of increasing magnetic flux density values.

9.4 *Setting Magnetic Flux Density*—With switches S_1 and S_3 closed, S_4 closed to the test fixture side, and S_2 and S_5 open, increase the voltage of the power supply until the flux voltmeter indicates the value of voltage calculated to give the desired test magnetic flux density in accordance with the equation of 10.1 or the equation of 11.1. Because the action of the air-flux compensator causes a voltage equal to that which would be induced in the secondary winding by the air flux to be subtracted from that induced by the total flux in the secondary, the magnetic flux density calculated from the voltage indicated by the flux voltmeter will be the intrinsic induction, B_i. In most cases, the values of intrinsic induction, B_i, are not sufficiently different from the corresponding values of normal induction, B, to require that any distinction be made. Where $\Gamma_m H_p$ is no longer insignificantly small compared to B_i, as at very high magnetic flux densities, determine the value of B by adding to B_i either the measured value of $\Gamma_m H_p$ or a nominal value known to be reasonably typical of the class of material being tested.

9.5 *Core Loss*—When the voltage indicated by the flux voltmeter has been adjusted to the desired value, read the wattmeter. Some users, particularly those having wattmeters compensated for their own losses (or burden), will desire to open switch S_4 before reading the wattmeter to eliminate the flux voltmeter burden from the wattmeter indication. Others will likely choose to have S_4 and S_5 closed when measuring the losses, so that all instruments may be read at the same time. In the latter case, the combined resistance load of the flux voltmeter, rms voltmeter, and potential circuit of the wattmeter will constitute the total instrument burden on the wattmeter.

Exercise care so that the combined current drain of the instruments does not cause an appreciably large voltage drop in the secondary circuit impedance of the test fixture. In such a case, the true magnetic flux density in the specimen may be appreciably higher than is apparent from the voltage measured at the secondary terminals of the test fixture. In any event, power as a result of any current drain in the secondary circuit at the time of reading the wattmeter must be known so it can be subtracted from the wattmeter indication to obtain the net watts caused by core loss.

9.6 *Specific Core Loss*—Obtain the specific core loss of the specimen in watts per unit mass at a specified frequency by dividing the net watts by that portion of the mass of the specimen constituting the active magnetic flux path in the specimen. Equations and instructions for computing the active mass of the specimen and the specific core loss are given in 10.2 and 11.2.

9.7 *Secondary RMS Voltage*—Read the rms voltmeter with the switch S_4 closed to the test fixture side, switch S_5 closed, and the voltage indicated by the flux voltmeter adjusted to the desired value. On truly sinusoidal voltage, both voltmeters will indicate the same value, showing that the form factor of the induced voltage is 1.111. When the voltmeters give different readings, the ratio of the rms value to the value indicated by the flux voltmeter reveals the amount by which the form factor of the induced voltage deviates from the desired value of 1.111. Determining the magnetic flux density from the reading of a flux voltmeter assures that the correct value of peak magnetic flux density is achieved in the specimen and, hence, that the hysteresis component of the core loss is correct even if the waveform is not strictly sinusoidal. However, the eddy-current component of the core loss (caused by current resulting from a nonsinusoidal voltage induced in the cross section of the strip) will be in error depending on the deviation of the induced voltage from the desired sinusoidal wave shape. This error in the eddy-current component of loss can be readily corrected by calculations based on the observed form factor and the approximate percentage of eddy-current loss for the grade of material being tested if the correction is reasonably small. The equations involved in determining this correction are given in 10.3 and 11.3.

9.8 *Peak Current*:

9.8.1 *Mutual Inductor*—When peak permeability at a given peak magnetic field strength is required, open S_1 to insert the primary of the mutual inductor, close S_2 to protect the wattmeter from the possibility of excessive current, open S_3 and S_5 to minimize secondary loading, and close S_4 toward the mutual-inductor side. Then adjust the voltage of the power supply such that the flux voltmeter indicates that the necessary value of the peak exciting current (calculated using the equations of 10.4.1 and 10.5 or the equations of 11.4 and 11.5) has been established. At this point, throw S_4 towards the test-fixture side and observe on the flux voltmeter the value of flux volts induced in the secondary winding of the test fixture. The magnetic flux density corresponding to the observed flux volts may be computed using the equation of 10.1 or the equation of 11.1. The equation for determining peak permeability is given in 10.6 and in 11.6.

9.8.2 *Peak-Reading Voltmeter*—If the peak-reading voltmeter and standard resistor are used instead of the mutual inductor and flux voltmeter for determining peak current, follow the same procedure as in 9.8.1 except use S_4 only on the test-fixture side and adjust the voltage of the power supply such that the peak-reading voltmeter indicates that the necessary value of the peak exciting current (calculated using the equations of 10.4.2 and 10.5 or the equations of 11.4 and 11.5) has been established. The equation for determining peak permeability is given in 10.6 and in 11.6.

10. Calculations (Customary Units)

10.1 *Flux Voltage*—Calculate the flux voltage, E_f in volts, induced in the secondary winding of the test fixture corresponding to the desired intrinsic test induction in the test specimen from the equation as follows:

$$E_f = \sqrt{2}\pi \, B_i A N_2 f \times 10^{-8} \tag{1}$$

where:

B_i = maximum intrinsic induction, G;
A = effective cross-sectional area of the test specimen, cm ^{2};
N_2 = number of turns in secondary winding; and
f = frequency, Hz.

Cross-sectional area, A in square centimetres, of the test specimen is determined as follows:

$$A = m/\ell\delta \tag{2}$$

where:

m = total mass of specimen, g;
ℓ = actual length of specimen, cm; and
δ = standard assumed density of specimen material, g/cm ^{3}.

NOTE 3—Information on standard assumed densities for commonly used magnetic materials can be found in Practice A34/A34M, Section 8.

10.2 *Specific Core Loss*—To obtain specific core loss in watts per unit mass of the specimen, power expended in the secondary of the test circuit and included in the wattmeter indication must be eliminated prior to dividing by the active mass of the specimen. The equation for calculating specific core loss, $P_c(B;f)$ in watts per pound, for a specified magnetic flux density, B, and frequency, f, is as follows:

$$P_{c(B;f)} = 453.6 \, (N_1 P_c / N_2 - E^2/R)/m_1 \tag{3}$$

where:

P_c = core loss indicated by the wattmeter, W;
E = rms value of secondary voltage, V;
R = parallel resistance of wattmeter potential circuit and all other loads connected to the secondary circuit, Ω;
N_1 = number of turns in primary winding;
N_2 = number of turns in secondary winding; and
m_1 = active mass of specimen, g.

The active mass, m_1 in grams, of the specimen is determined as follows:

$$m_1 = \ell_{1m/\ell} \tag{4}$$

where: