



# Standard Practice for Calibration of Standards and Equipment for Electrical Insulating Materials Testing<sup>1</sup>

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## 1. Scope

1.1 This practice provides for the establishment and maintenance of calibration procedures for measuring and test equipment used for electrical insulating materials. It provides a framework of concepts and practices, with definitions and specifications pertaining to measurement, adequacy of standards, necessary environmental controls, tables of corrections, intervals of calibration, calibration procedures, calibration of standards, and personnel training system documentation.

1.2 This practice is intended for control of the accuracy of the equipment used for measurements that are made in accordance with ASTM standards or other specified requirements.

1.3 *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:

~~D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing<sup>2</sup>~~

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee ~~D-9~~ D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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Ð 1711 Terminology Relating to Electrical Insulation<sup>2</sup>

D 2645 Tolerances for Yarns Spun on the Cotton or Worsted Systems<sup>3</sup>

D 6054 Practice for Conditioning Electrical Insulating Materials for Testing<sup>4</sup>

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials<sup>5</sup>

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods<sup>6</sup>

### 3. Terminology

3.1 *Definitions*—Many definitions concerning calibration of standards and equipment are generally understood or defined in other ASTM standards such as Practice E 177 and D 2645. Only those terms bearing on interpretations are described here.

3.1.1 See Terminology D 1711 for terms pertaining to electrical insulating materials.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accuracy ratio, n*—see *uncertainty ratio*.

3.2.2 *adequacy of a standard, n*—the quality or state of a standard that exhibits and maintains the required accuracy and stability under the conditions of usage.

3.2.3 *calibration, n*—the process of comparing a standard or an instrument with one of greater accuracy (smaller uncertainty) for the purpose of obtaining quantitative estimates of the actual value of the standard being calibrated, the deviation of the actual value from the nominal value, or the difference between the value indicated by an instrument and the actual value.

3.2.3.1 *Discussion*—These differences are usually tabulated in a “Table of Corrections” which apply to that particular standard or instrument.

3.2.4 *calibration labeling, n*—for measurement equipment or standards, a means to indicate the date of latest calibration, by whom it was calibrated, and the due date for the next calibration.

3.2.5 *certification*—see *traceability to NIST (formerly NBS)*.

3.2.5.1 *Discussion*—In the past, certification has been used to convey the meaning of either or both of the above terms. Since NIST no longer issues certificates of calibrations, the term has come to have a specialized meaning. The following is quoted from *NBS Special Publication 250*, “Calibration and Test Services of the National Institute of Standards and Technology”, 1968 edition:

“Results of calibrations and other tests are issued to the customer as formal reports entitled, “National Institute of Standards and Technology Report of Calibration”, “National Institute of Standards and Technology Report of Test”, or “National Institute of Standards and Technology Report of Analysis”, as appropriate. Copies are not supplied to other parties. Whenever formal certification is required by law, or to meet special conditions adjudged by the National Institute of Standards and Technology to warrant it, a letter will be provided certifying that the particular item was received and calibrated or tested and identifying the report containing the results.”

3.2.6 *degree of usage, n*—the summation of all factors bearing upon the stability of accuracy and reproducibility of a standard or an instrument.

3.2.6.1 *Discussion*—Some, but not all, examples of such factors are: frequency of use; hours in service; hours on bench, in storage, and in transit; roughness in handling; number and nature of overloads; changes in ambient conditions such as temperature, humidity, vibration, contamination of insulators, electrical contacts, and mating surfaces; aging processes, especially of limited life components such as electron tubes; exposure to radiations, etc.

3.2.7 *environmental control, n*—the maintenance of ambient conditions within prescribed limits such as to ensure the validity of the calibrations of measuring and test equipment or standards.

3.2.7.1 *Discussion*—The value of a standard and the corrections for measuring equipment can be influenced by changes in temperature, humidity, pressure, radiation, etc., and it is necessary to place reasonable limits on these variables.

3.2.8 *interval of calibration, n*—the elapsed time permitted between calibrations as required by the pertinent specifications, or when not specified, as determined under procedures in this practice.

3.2.9 *qualified personnel, n*—persons adequately trained in the applicable test procedures, equipment operations, and calibration procedures.

3.2.10 *systematic error, n*—the inherent bias (offset) of a measurement process, or of one of its components.

3.2.11 *system control, n*—a recommended control of methods, procedures, and practices to ensure acceptable uniformity and continuity of equipment and personnel operations in a measuring system.

3.2.12 *traceability to NIST, n*—a documented chain of comparisons connecting a working standard (in as few steps as is practicable) to a standard maintained by the National Institute of Standards and Technology.

3.2.13 *uncertainty, n*—an allowance assigned to a measured value to take into account two major components of error: (1) the systematic error, and (2) the random error attributed to the imprecision of the measurement process.

3.2.14 *uncertainty ratio, n*—the ratio of the uncertainties of two standards.

<sup>2</sup> MIL-C-45662B, Military Specification Calibration Program Requirements, Draft 6, February, 1969.

<sup>3</sup> Annual Book of ASTM Standards, Vol 10.01.

<sup>4</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 10.042.

<sup>6</sup> Annual Book of ASTM Standards, Vol 15.09.

<sup>6</sup> Annual Book of ASTM Standards, Vol 14.02.

#### 4. Significance and Use

4.1 The accuracy and precision of any measurement can be established only with reference standards by processes involving comparisons and calibrations based upon a commonly accepted groundwork of standards and definitions. Even in those instances where the accuracy of a standard cannot be established, comparisons on a relative basis require that a reference standard be maintained, and that all comparisons be made in terms of deviations from this reference standard. Thus standards and calibrations are fundamental to the entire measurement process.

4.2 Conformance or non-conformance to specifications or standards agreed upon between the consumer and supplier can be established only by measurements and comparisons based upon a well defined and commonly accepted groundwork.

4.3 The accuracy and precision of measuring equipment may deteriorate with time, use, and environmental conditions. Unless sufficient accuracy is maintained, errors in test results may lead to the acceptance of faulty materials or workmanship, or the rejection of a satisfactory product.

#### 5. System Control

5.1 To ensure uniformity of understanding and performance, and continuity of satisfactory operations when personnel changes occur, it is necessary that all proposed or existing procedures or practices intended to implement the equipment and standards calibration system be documented (preferably in book form). This documentation should provide a complete detailed plan for controlling the accuracy of every item of measuring and test equipment, and every measurement standard utilized. A method, procedure, or standard practice should be prescribed as follows:

5.1.1 A listing of all measurement standards with proper nomenclature and identification numbers.

5.1.2 A listing of intervals of calibration assigned for measuring and test equipment and for each measurement standard, both reference and transfer, and calibration sources designated for these items.

5.1.3 A listing of environmental conditions in which the standards, and measuring and test equipment are utilized and calibrated.

5.1.4 A listing of calibration procedures for all standards and equipment.

5.1.5 A listing of calibration reports for all measurement standards and for equipment whose accuracy requirement is such that a report is necessary.

5.1.6 Documented proof that the calibration system is coordinated with the inspection system or Quality Control Program.

5.1.7 Documented proof that provisions have been made by a system of periodic inspections or cross checks in order to detect differences, erratic readings, and other performance degrading factors which cannot be anticipated or provided for by calibration intervals. Also, that provisions have been made for timely and positive corrective action.

5.1.8 A listing of the coding system used for calibration labeling with explanations and specimens of labels, decals, reject tags, and the like.

5.1.9 Specimens of forms used in the laboratory's record system, such as instrument and gage record cards, data sheets, test reports, certifications, reject forms and the like, should be available.

5.1.10 Detailed results of all calibration and comparisons compiled separately for each standard or piece of equipment.

#### 6. Environmental Control

6.1 Measuring and test equipment and measurement standards should be calibrated and utilized in an environment controlled to the extent necessary to ensure continued measurements of required accuracy, giving due consideration to temperature, humidity, vibration, cleanliness, and other controllable factors affecting precision measurements. The recommended environment is:

6.1.1 Calibrations of standards and equipment shall be performed in a standard laboratory atmosphere, as defined in Practice ~~D 618~~; D 6054. This specifies a temperature of  $23 \pm 2^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and  $50 \pm 5\%$  relative humidity. If any other atmosphere is required because of special considerations, strong preference should be given to those allowed by ISO, as described in Specification E 171. These are:

$$20 \pm 2^\circ\text{C} \text{ and } 65 \pm 5\% \text{ relative humidity} \quad (1)$$

$$27 \pm 2^\circ\text{C} \text{ and } 65 \pm 5\% \text{ relative humidity}$$

6.1.2 A filtered air supply is recommended in the calibration area, preferably containing less than  $2.0 \times 10^5$  particles over  $1 \mu\text{m}$  in size/ft<sup>3</sup> of air. The area should have positive pressure and smoking, eating, and drinking should be prohibited.

6.1.3 Electrical power within the laboratory should include: voltage regulation to at least 2%, minimum line transients as caused by interaction of other users or a separate main line to the laboratory (separate input power if possible), and a suitable grounding system established to ensure equal potentials to ground throughout the laboratory, (or isolation transformers may be used to separate individual equipment).

6.1.4 Lighting levels of 80 to 100-ft candles should be provided for work bench areas and 60 to 80-ft candles for work surfaces. Fluorescent lights should be shielded properly and grounded to reduce electrical noise.

#### 7. Procedure

7.1 *Calibration of Reference Standards:*

7.1.1 *Primary Standards*—Calibrate each system's primary reference standard, where possible, by comparison with the most accurate standard available in its field; this is usually found at the National Institute of Standards and Technology. Then use the

system's primary standard to calibrate the secondary standards. Keep the primary standards degree of usage and movement at an absolute minimum. Keep it under constant environmental conditions where possible and preferably under lock.

7.1.2 *Secondary Standards*—Calibrate against the primary reference standard, then use the system's secondary standards to calibrate working standards, or measuring and test equipment. The secondary standards' degree of usage depends on the accuracy variation of the working standards and test equipment. Cross check standards to help evaluate the accuracy variation.

7.1.3 *Accuracy*—Specify the required accuracy of the calibration standards in writing. If the accuracy is not specified, it is preferable that the calibration uncertainty of the calibration standard is known to be less than 25% of the smallest value measurable on the equipment being calibrated. In other words, the uncertainty ratio of the calibrated equipment to the standard shall be at least 4 to 1. This uncertainty ratio shall be based on measured values, not on nominal values or manufacturers' published values. In some cases, as where standards comparable in quality to the national standard must be calibrated by comparison to the national standard, a 4 to 1 ratio may be impractical and this requirement must be adjusted to suit the circumstances.

7.1.4 *Interval of Calibration*—The interval of calibration is dependent on the degree of usage, environmental conditions, degree of accuracy desired, aging characteristics of the standard, repeatability performance, and many other factors. When a definite calibration interval is not given for the standard, the following procedure is recommended. Under close surveillance and with cross checks and functional standards monitoring the system, calibrate the standard at 6-month intervals over a period of 3 years. If all calibrations fall within the specified accuracy and show no significant changing trend, extend the calibration interval to 1 year and continue for 3 years. If no significant changes occur, extend the calibration interval to 2 years and continue with the 2 year interval until significant changes occur.

7.1.4.1 If significant changes in the standard are observed during the semi-annual calibration, corrective action is required and the semi-annual interval continued as long as necessary. If changes are observed after the calibration interval has been extended, it is necessary to fall back to shorter intervals until the changes have reduced to a tolerable level or have been eliminated by corrective action. Separate documentation of each calibration and interval change is necessary. This documentation is discussed in Section 5. In cases where the standard fails to meet the accuracy limits and adjustments are made, the calibration interval reverts back to the previous time interval and continues with that interval until five consecutive acceptable calibrations occur, at which time the extension of the interval begins as before. Document adjustments and level shifts. In all cases, use the calibration value of a standard.

7.1.5 *Table of Corrections*—Calibration of a standard yields quantitative data in the form of errors or deviations from the true value. These data are useful when tabulated in a "Table of Corrections" which can be applied to the nominal or indicated value of the standard in order to obtain the true value.

## 7.2 *Calibration of Measuring and Test Equipment:*

7.2.1 *Calibration*—Calibrate the measuring and test equipment by using primary, secondary, working, or interim standards that ensure adequate accuracy.

7.2.2 *Adequate Accuracy*—Specify the required accuracy of measuring and test equipment in writing. If accuracy is not specified, standard practice calls for the uncertainty of the measuring or test equipment to be less than  $\frac{1}{4}$  the allowable uncertainty (tolerance) of the quantity being measured. For example, if the specified thickness of a bar is  $0.100 \pm 0.001$  cm ( $1.000 \pm 0.010$  mm), the micrometer used for this measurement should have a calibration uncertainty of  $\pm 0.00025$  cm ( $\pm 0.00250$  mm) or less. In other words, the ratio of the allowable uncertainty of the quantity being measured to the uncertainty of the measuring equipment should be 4 to 1, if practical.

7.2.3 *Interval of Calibration*—Interval of calibration for measuring and test equipment is dependent on the degree of usage, environmental conditions, degree of accuracy desired, aging characteristics of the equipment, handling and shipping practices, personnel training and practices, and the like. Calibration facilities which handle a relatively large number of calibrations of one type or class of instrument can build up statistical data sufficient to arrive at an optimum calibration interval for each type of instrument. (See Appendix X1.)

7.2.3.1 When statistical data are unavailable for a particular type of measuring or test equipment, the following procedure is recommended: Under close surveillance, and with periodic functional checks monitoring the system, calibrate the equipment initially and then calibrate monthly for 6 months. If all seven calibrations fall within the desired accuracy and show no significant changing trend, extend the calibration interval to 6 months. Continue for three additional calibrations, and if no significant changes occur, extend the calibration interval to 1 year and continue with this calibration interval until significant changes occur. One year is the maximum calibration interval recommended for test and measuring equipment.

7.2.4 *Table of Corrections*—Calibration of measuring or test equipment yields quantitative data in the form of errors or deviations from the true value. These data are useful when tabulated as a Table of Corrections, that can be applied to the nominal or indicated value of the measuring equipment in order to obtain the true value.

## 8. Personnel Training

8.1 Personnel training must provide: a background in the field of measurement, instruction in procedures of calibrations on the equipment, and instruction in the operation of the equipment or standard, or both.

## 9. Report

9.1 The presentation of data must provide the information required under Sections 5 and 6. Individual records for each standard

or piece of measuring and test equipment are necessary, including calibration labeling.

## **10. Keywords**

10.1 accuracy; calibration; error; insulating materials; reference standards

## **APPENDIX**

(Nonmandatory Information)

### **X1. EXAMPLES OF INTERVALS OF CALIBRATION FOR INSTRUMENTS**

X1.1 One large electrical manufacturing company<sup>7</sup> has developed a guide to calibration intervals for several classes of instruments and reference standards based on the Poisson Distribution and calculated on the basis of 90 % confidence level. The results are summarized here.

| Months<br>Calibration Interval | Number of<br>Types of Equipment |
|--------------------------------|---------------------------------|
| 12                             | 12                              |
| 6                              | 38                              |
| 3                              | 39                              |
| 2                              | 8                               |
| 1                              | 3                               |

X1.2 The 12 months calibration interval was permissible on analytical balances, balance weights (Class S and S1), decade resistors, directional couplers, fixed inductors, fixed resistors, Q standards, ratio transformers, standard capacitors, thermometers (glass), and voltage dividers. The 1-month calibration interval was necessary on some digital voltmeters, some oscilloscope pre-amplifiers, and some vacuum tube voltmeters.

X1.3 A 3-month calibration interval was required on portable voltmeters, ammeter, wattmeters, voltohmmeters, oscilloscopes, radiation survey instruments, temperature controllers, tensile testers, thermometers (bimetallic), console meter calibrators, voltage and current recorders, potentiometers (thermocouple), Q meters, some capacitance bridges, and some vacuum tube voltmeters.

X1.4 A 6-month calibration interval was required on some capacitance bridges, resistance bridges, megohmmeters, standing wave indicators, thermocouples, pressure gages and some vacuum tube voltmeters.

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## ***Annual Book***

<sup>7</sup>Seamans, P. A., "Instrument Calibration Records; Establishment of ASTM Standards, Vol 14.02: a High Confidence Data Bank," *Electronics Laboratory Report, R69 ELS-115, General Electric Co.*

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