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Practice for use of a polymethylmethacrylate dosimetry system

Pratique de l'utilisation d'un système dosimétrique au polyméthylméthacrylate

Reference number
ISO/ASTM 51276:2002(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

ASTM International is one of the world's largest voluntary standards development organizations with global participation from affected stakeholders. ASTM technical committees follow rigorous due process balloting procedures.

A pilot project between ISO and ASTM International has been formed to develop and maintain a group of ISO/ASTM radiation processing dosimetry standards. Under this pilot project, ASTM Subcommittee E10.01, Dosimetry for Radiation Processing, is responsible for the development and maintenance of these dosimetry standards with unrestricted participation and input from appropriate ISO member bodies.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. Neither ISO nor ASTM International shall be held responsible for identifying any or all such patent rights.

International Standard ISO/ASTM 51276 was developed by ASTM Committee E10, Nuclear Technology and Applications, through Subcommittee E10.01, and by Technical Committee ISO/TC 85, Nuclear Energy.

Annex A1 of this International Standard is for information only.

Standard Practice for Use of a Polymethylmethacrylate Dosimetry System[1]

This standard is issued under the fixed designation ISO/ASTM 51276; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision.

1. Scope

1.1 This practice covers procedures for using hermetically-sealed polymethylmethacrylate (PMMA) dosimeters for measuring absorbed dose in materials irradiated by photons or electrons in terms of absorbed dose in water.

1.2 This practice covers systems that permit absorbed dose measurements under the following conditions:

1.2.1 The absorbed dose range is 0.1 to 100 kGy.

1.2.2 The absorbed dose rate is 1×10^{-2} to 1×10^{7} Gy·s^{-1}.

1.2.3 The radiation energy range for photons is 0.1 to 50 MeV, and for electrons 3 to 50 MeV.

1.2.4 The irradiation temperature is −78 to +50°C.

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:*

E 170 Terminology Relating to Radiation Measurements and Dosimetry[2]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[3]

E 178 Practice for Dealing with Outlying Observations[3]

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers[4]

E 456 Terminology Relating to Quality and Statistics[3]

E 668 Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices[2]

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System[2]

2.2 *ISO/ASTM Standards:*

51204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing[2]

51205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System[2]

51261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing[2]

51400 Practice for Characterization and Performance of a High-Dose Radiation Dosimetry Calibration Laboratory[2]

51401 Practice for Use of a Dichromate Dosimetry System

51607 Practice for Use of the Alanine-EPR Dosimetry System[2]

51631 Practice for Use of Calorimetric Dosimetry Systems for Electron Beam Dose Measurements and Dosimeter Calibrations[2]

51707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing[2]

2.3 *International Commission on Radiation Units and Measurements (ICRU) Reports:*

ICRU Report 14 Radiation Dosimetry: X Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 50 MeV[5]

ICRU Report 17 Radiation Dosimetry: X Rays Generated at Potentials of 5 to 150 kV[5]

ICRU Report 34 The Dosimetry of Pulsed Radiation[5]

ICRU Report 35 Radiation Dosimetry: Electron Beams with Energies Between 1 and 50 MeV[5]

ICRU Report 60 Radiation Quantities and Units[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorbed dose (D)*—quantity of ionizing radiation energy imparted per unit mass of a specified material. The SI unit of absorbed dose is the gray (Gy), where 1 gray is equivalent to the absorption of 1 joule per kilogram of the specified material (1 Gy = 1 J/kg). The mathematical relationship is the quotient of $d\bar{\epsilon}$ by dm, where $d\bar{\epsilon}$ is the mean incremental energy imparted by ionizing radiation to matter of incremental mass dm (see ICRU Report 60).

$$D = \frac{d\bar{\epsilon}}{dm} \tag{1}$$

3.1.1.1 *Discussion*—The discontinued unit for absorbed dose is the rad (1 rad = 100 erg per gram = 0.01 Gy). Absorbed dose is sometimes referred to simply as dose.

3.1.2 *absorbed-dose rate ($\dot{D}$)*—the absorbed dose in a material per incremental time interval, that is, the quotient of

[1] This practice is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.01 on Dosimetry for Radiation Processing, and is also under the jurisdiction of ISO/TC 85/WG 3.

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[2] *Annual Book of ASTM Standards*, Vol 12.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

[5] Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, U.S.A.

dD by *dt* (see ICRU Report 60).

$$\dot{D} = \frac{dD}{dt} \tag{2}$$

Unit: $Gy \cdot s^{-1}$.

3.1.2.1 *Discussion*—The absorbed-dose rate is often specified in terms of average value of $\dot{D}$ over long-time intervals, for example, in units of $Gy \cdot min^{-1}$ or $Gy \cdot h^{-1}$.

3.1.3 *analysis wavelength*—wavelength used in a spectrophotometric instrument for the measurement of optical absorbance.

3.1.4 *calibration curve*—graphical representation of the dosimetry system's response function.

3.1.5 *calibration facility*—combination of an ionizing radiation source and its associated instrumentation that provides a uniform and reproducible absorbed dose or absorbed-dose rate traceable to national or international standards, at a specified location and within a specific material, and that may be used to derive the dosimetry system's response function or calibration curve.

3.1.6 *dosimeter*—a device that, when irradiated, exhibits a quantifiable change in some property of the device which can be related to absorbed dose in a given material using appropriate analytical instrumentation and techniques.

3.1.7 *dosimeter batch*—quantity of dosimeters made from a specific mass of material with uniform composition, fabricated in a single production run under controlled, consistent conditions, and having a unique identification code.

3.1.8 *dosimeter response*—the reproducible, quantifiable radiation effect produced by a given absorbed dose.

3.1.9 *dosimeter stock*—part of a dosimeter batch held by the user.

3.1.10 *dosimetry system*—a system used for determining absorbed dose, consisting of dosimeters, measurement instruments and their associated reference standards, and procedures for the system's use.

3.1.11 *electron equilibrium*—a condition that exists in material under irradiation if the kinetic energies, number, and direction of electrons induced by the radiation are uniform throughout the measurement volume of interest. Thus, the sum of the kinetic energies of the electrons entering the volume equals the sum of the kinetic energies of the electrons leaving the volume (see ICRU Report 60).

3.1.11.1 *Discussion*—Electron equilibrium is often referred to as charged particle equilibrium (see ASTM Terminology E 170 and ICRU Report 60).

3.1.12 *measurement quality assurance plan*—a documented program for the measurement process that assures on a continuing basis that the overall uncertainty meets the requirements of the specific application. This plan requires traceability to, and consistency with, nationally or internationally recognized standards.

3.1.13 *mean specific absorbance* ($\bar{k}$)—average value of *k* for a set of dosimeters irradiated to the same absorbed dose, under the same conditions.

$$\bar{k} = \frac{1}{n} \sum_{i=1}^{n} k_i \tag{3}$$

where:

n = number of dosimeters, and
k_i = individual dosimeter specific absorbance.

3.1.14 *polymethylmethacrylate (PMMA) dosimeter*—piece of specially selected or specially developed PMMA material that exhibits characterizable ionizing radiation-induced changes in specific optical absorbance as a function of absorbed doses, individually sealed by the manufacturer in a hermetically sealed pouch.

3.1.14.1 *Discussion*—The PMMA piece, when removed from the pouch, is still referred to as the dosimeter.

3.1.15 *reference–standard dosimeter*—a dosimeter of high metrological quality, used as a standard to provide measurements traceable to and consistent with measurements made using primary–standard dosimeters (see ISO/ASTM Guide 51261).

3.1.16 *response*—see *dosimeter response*.

3.1.17 *response function*—mathematical representation of the relationship between dosimeter response and absorbed dose for a given dosimetry system.

3.1.18 *routine dosimeter*—dosimeter calibrated against a primary-, reference-, or transfer-standard dosimeter and used for routine absorbed-dose measurement (see ISO/ASTM Guide 51261).

3.1.19 *simulated product*—a mass of material with attenuation and scattering properties similar to those of the product, material, or substance to be irradiated.

3.1.19.1 *Discussion*—Simulated product is used during irradiator characterization as a substitute for the actual product, material, or substance to be irradiated. When used in routine production runs, it is sometimes referred to as compensating dummy. When used for absorbed-dose mapping, simulated product is sometimes referred to as phantom material.

3.1.20 *specific absorbance (k)*—absorbance, *A*, at a selected wavelength divided by the optical path length, *d*, through the dosimeter, as follows:

$$k = A/d \tag{4}$$

3.1.20.1 *Discussion*—In this practice (ISO/ASTM 51276), *d* is equated to dosimeter thickness (*t*). If *t* is virtually constant (within ±1 %), calculation of specific absorbance is unnecessary, and absorbance *A* may be taken as the dose-related quantity.

3.1.21 *traceability*—the documentation demonstrating by means of an unbroken chain of comparisons that a measurement is in agreement within acceptable limits of uncertainty with comparable nationally or internationally recognized standards.

3.1.22 *transfer–standard dosimeter*—a dosimeter, often a reference–standard dosimeter, suitable for transport between different locations, used to compare absorbed-dose measurements (see ISO/ASTM Guide 51261).

3.1.23 *uncertainty*—a parameter associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand or derived quantity.

3.1.23.1 *Discussion*—The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width

of an interval having a stated confidence.

3.1.23.2 *Discussion*—Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. The other components, which also can be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

3.1.23.3 *Discussion*—It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

3.2 Other appropriate terms may be found in ASTM Terminology E 170.

4. Significance and Use

4.1 Polymethylmethacrylate dosimetry systems are commonly applied in industrial radiation processing, for example, in the sterilization of medical devices and the processing of foods. In these applications, doses fall mostly within the 0.1 to 100 kGy working range of the family of PMMA dosimeters.

4.2 Properly selected PMMA dosimeter materials provide a means of directly estimating absorbed doses in near water-equivalent substances, such as plastics, cotton, paper, gut, and rubber. The doses are normally expressed in terms of dose in water (see 4.7). Under the influence of ionizing radiation, chemical reactions take place in the material, creating and/or enhancing absorption bands in the visible and/or ultraviolet regions of the spectrum. Absorbance is determined at selected wavelengths within these radiation-induced absorption bands. Examples of appropriate wavelengths used for analysis of specific dosimeters are provided in Table A1.1.

4.3 In the application of a specific dosimetry system, absorbed dose is determined by using an experimentally derived calibration curve. The calibration curve is determined by measuring sets of dosimeters irradiated to known absorbed doses that adequately span the range of utilization of the system (see 7.5.2).

4.4 Polymethylmethacrylate dosimetry systems require calibration traceable to national or international standards. See ISO/ASTM Guide 51261.

4.5 During calibration and use, possible effects of conditions such as temperature, light exposure, energy spectrum, and absorbed dose rate are taken into account.

4.6 Unprotected PMMA dosimeter material is sensitive to changes in humidity, and cut pieces are therefore individually sealed in water impermeable pouches at the manufacturing stage. They must be kept in these sealed pouches during irradiation.

4.7 Absorbed dose in materials other than water may be determined by applying conversion factors in accordance with ISO/ASTM Guide 51261.

NOTE 1—For a comprehensive discussion of various dosimetry methods applicable to the radiation types and energies discussed in this practice, see ICRU Reports 14, 17, 34, and 35.

5. Apparatus

5.1 *Components of the PMMA Dosimetry System*—The following shall be used to determine absorbed dose with PMMA dosimetry systems:

5.1.1 *Polymethylmethacrylate Dosimeters*.

5.1.2 *Spectrophotometer* (or an equivalent instrument), capable of determining optical absorbance at the analysis wavelength and having documentation covering analysis wavelength range, accuracy of wavelength selection and absorbance determination, spectral bandwidth, and stray light rejection.

5.1.3 *Holder*, to position the dosimeter reproducibly in, and perpendicular to, the analyzing light beam.

5.1.4 *Calibrated Thickness Gage*.

5.1.5 Calibrated thickness gage blocks covering the range of thicknesses encountered.

NOTE 2—For constant thickness dosimeters (see 3.1.20.1) documentation provided by the manufacturer of the PMMA dosimeter with regard to the thickness and its uniformity must first be verified by the user for a representative sample, and may then be substituted for direct measurement by the user.

5.1.6 Calibration curve or response function (see 7.5.6).

6. Performance Check of Instrumentation

6.1 Check and document the uncertainties of the wavelength and absorbance scales of the spectrophotometer at or near the analysis wavelength at documented time intervals during periods of use, or whenever there are indications of poor performance. Compare and document this information with the original instrument specifications to verify adequate performance. (See ASTM Practices E 275 and E 1026.)

6.2 Check the thickness gage before, during, and after use to assure reproducibility and lack of zero drift. Check and document the calibration of the gage at documented time intervals. Use gage blocks traceable to national standards for this purpose.

7. Calibration of Dosimeters

7.1 Calibration of PMMA dosimeters can be accomplished by irradiating the dosimeters in a calibration facility, or by irradiating the dosimeters, along with reference or transfer–standard dosimeters in a production irradiator (see ISO/ASTM Guide 51261).

7.2 The gamma- or electron-beam facility used may be an accredited calibration facility that provides an absorbed-dose rate measured by reference or transfer–standard dosimeters, or it may be a production irradiator. If a production irradiator is used, the absorbed doses delivered to the calibration dosimeters shall be determined by means of reference or transfer–standard dosimeters irradiated together with the dosimeters to be calibrated, under conditions that ensure that the calibration- and corresponding reference- or transfer-standard dosimeter sets receive the same dose, under the same environmental conditions.

NOTE 3—The radiation response of PMMA dosimeters may be affected by extremes of environmental or seasonal conditions, such as absorbed dose rate and temperature found in some production irradiators (see Refs

1-10, **17-19**, and **25**).[6] In these circumstances the use of dosimeter calibrations performed at fixed dose rates and fixed temperatures could result in unacceptably large increases in dosimetric uncertainty. If prior experience, manufacturer's recommendations, or scientific literature suggest that the range of environmental conditions met by the dosimeters in the production facility are likely to significantly increase the uncertainties, then the PMMA dosimeters should be calibrated in an environment that encompasses these conditions. This type of calibration may, for example, be carried out using the production irradiator, under the conditions identified, using reference- or transfer-standard dosimeters to determine the calibration doses given.

7.3 Absorbed doses shall be specified in terms of absorbed dose in water, or in another specified material appropriate for the particular application.

7.4 Provide the following conditions for the calibration of dosimeters:

7.4.1 Ensure that the shelf-life of the dosimeters, as stated by the manufacturer, has not been exceeded.

7.4.2 Select a well defined and reproducible position for the dosimeters during irradiation in the calibration field. In the case of a fixed dose rate calibration, select a location in the calibration field in which the variation in absorbed dose rate within the volume occupied by the dosimeters has been demonstrated to be within ±1 %. For variable dose rate calibration in a production irradiator, use a location in the product, or simulated product, in which the variation of absorbed dose delivered during production has been demonstrated to be within ±1 %.

7.4.3 If a calibration facility is used, the dose rate shall be traceable to national or international standards. The temperature of the dosimeters, both during and after irradiation, and the fixed dose rate used shall be arranged to be as close as practicable to the average irradiation temperature, average post irradiation temperature/time, and average dose rate conditions occurring in the actual production facility of interest.

7.4.4 Whatever the irradiation conditions used, the dosimeters shall be surrounded with sufficient PMMA or equivalent material to ensure electron equilibrium conditions.

NOTE 4—As an example, for cobalt-60 gamma irradiations, 3 to 5 mm of PMMA (or equivalent polymeric material, such as solid polystyrene) surrounding the dosimeters on all sides effectively ensures electron equilibrium conditions. In the case of calibrations in a production irradiator, the material should take the form of a block having a minimum wall thickness of 3 mm and containing a cavity, or cavities, geometrically located to ensure that the PMMA- and reference- or transfer-standard dosimeters all receive the same dose.

7.5 Calibrate each stock or batch of dosimeters prior to routine use. If a new stock from the same batch is to be brought into use, recalibration may not be necessary. However, it must be demonstrated that the existing calibration applies to the new stock, by means of a verification procedure (see Note 5).

NOTE 5—To verify that an existing calibration still applies, irradiate sets of dosimeters at selected doses spanning the range of utilization. A minimum effort is to irradiate dosimeters at the lower and upper limits of this range, and the mid-point. If the resulting values fit the existing calibration curve (any slight deviations being statistically insignificant), then the calibration is verified.

7.5.1 Use a set of at least four dosimeters for each absorbed dose point (see ASTM Practice E 668 for guidance on determining sample size).

7.5.2 The number of sets of PMMA dosimeters required to determine the calibration curve of the dosimetry system depends on the dose-range of utilization. Use at least five sets for each factor of ten span of absorbed dose, or at least four sets if the range of utilization is less than a factor of ten. For example, a range of use from 0.2 to 45 kGy would require at least twelve sets.

NOTE 6—To determine mathematically the minimum number of sets to be used, divide the maximum dose in the range of utilization (D_{max}) by the minimum dose (D_{min}), then, calculate log(base 10) of this ratio:

$$Q = \log (D_{max}/D_{min}) \quad (5)$$

If Q is less than 1, use a minimum of four sets, If Q is greater than 1, calculate the multiple $5 \times Q$, and round this to the nearest integer value. This value represents the minimum number of sets to be used.

7.5.3 Determine the specific absorbance of the dosimeters (see Section 8).

7.5.4 Calculate and document the mean specific absorbance, $\bar{k}$, and the sample standard deviation (S_{n-1}) for each set of four (or more) dosimeters at each dose value.

NOTE 7—The sample standard deviation, S_{n-1}, is calculated from the sample data set of n values as follows:

$$S_{n-1} = \sqrt{\frac{\Sigma(k_i - \bar{k})^2}{n-1}} \quad (6)$$

where:

k_i = i'th value of k.

7.5.5 For calibrations in a production irradiator, document the type, supplier, batch number, date of manufacture, and all other relevant information for the reference- or transfer-standard dosimeters used. Document the code number and title of the measurement practice used, the correction factors used (if applicable), and correlate the measured reference- or transfer-standard doses against the corresponding PMMA dosimeter specific absorbances.

7.5.6 Graphically plot mean specific absorbance versus absorbed dose, or use a suitable computer code, or both, to derive this relationship in mathematical form. Choose an analytical form (for example, linear, polynomial, or exponential) that provides the best fit to the measured data.

7.5.7 Examine the resulting calibration curve or response function for goodness of fit (see ISO/ASTM Guide 51707).

7.5.8 Repeat this calibration procedure if any value (or values) deviates significantly from the determined curve, and if discarding this value would result in there being insufficient data to adequately define the curve (see ISO/ASTM Guide 51707).

NOTE 8—See ASTM Practice E 178 for guidance on dealing with outlyers.

7.5.9 Repeat the calibration procedure at intervals not to exceed twelve months.

[6] The boldface numbers in parentheses refer to the bibliography at the end of this practice.

8. Procedures

8.1 *Examination and Storage Procedure*:

8.1.1 Inspect each dosimeter pouch for imperfections, for example, pouch seal violation. Discard any dosimeters that show unacceptable imperfections that could give rise to erroneous readings.

8.1.2 Store dosimeters according to the manufacturer's written recommendations.

8.2 *Dosimeter Irradiation Procedure*:

8.2.1 Mark the packaged dosimeters appropriately for identification.

8.2.2 For calibration, use an appropriate procedure as detailed in Section 7.

8.2.3 For general application in industrial process monitoring, place the packaged dosimeters at appropriate locations (see ISO/ASTM Practice 51204).

NOTE 9—For interpretation of absorbed dose, the dosimeters may be irradiated either in the product undergoing processing, in a medium of similar composition, or in simulated product. In each case, the medium should have appropriate dimensions so as to approximate electron equilibrium conditions. Such equilibrium conditions may not exist, however, within dosimeters placed throughout the product under actual processing conditions. This is particularly the case near interfaces of different materials. Irradiation under non-equilibrium conditions, such as on the surface of a product package, may nevertheless be sufficient to monitor the absorbed dose delivered to the product and may under certain conditions be related to absorbed dose within the product by correction factors. For a detailed discussion of this subject, see ISO/ASTM Guide 51261 and ISO/ASTM Practice 51204.

8.3 *Post-Irradiation Analysis Procedure*:

8.3.1 Keep dosimeters in their sealed packages until time for reading.

8.3.2 Inspect each dosimeter pouch for imperfections, for example, pouch violation. Document any imperfections.

8.3.3 Open the package and remove the dosimeter, handling it by its edges.

8.3.4 Inspect the dosimeter for any imperfections, such as scratches. Document any imperfections.

8.3.5 If necessary, clean the PMMA piece before analysis. An accepted method is wiping with paper tissue moistened with ethyl alcohol.

8.3.6 Position the piece in the holder, in the instrument, taking care to provide proper alignment and positioning perpendicular to the analyzing light beam.

8.3.7 Determine the absorbance at the selected analysis wavelength (see Table A1.1).

8.3.8 Measure the thickness of the PMMA piece in the region traversed by the analyzing light beam (see 3.1.20).

8.3.9 Calculate the specific absorbance (see 3.1.20).

9. Characterization of Each Stock of Dosimeters

9.1 *Reproducibility of Specific Absorbance*:

9.1.1 For each stock of dosimeters, the reproducibility of specific absorbance should be obtained by analyzing the sets of dosimeters irradiated during the calibration at each absorbed dose value (see 7.5.2).

9.1.2 Use the sample standard deviations, S_{n-1}, determined during calibration (see 7.5.4) to calculate coefficients of variation (CV) for each absorbed dose value, as follows:

$$CV = \frac{S_{n-1}}{\bar{k}} \times 100\ (\%) \quad (7)$$

9.1.3 Document these coefficients of variation and note any that are unusually large.

NOTE 10—In general, if any coefficient of variation values are greater than 2 %, then a redetermination of the data should be considered using a larger sample of dosimeters, or the stock of dosimeters should be rejected.

9.2 *Post-Irradiation Characterization*:

9.2.1 Under certain conditions, dosimeters may not develop full color immediately after irradiation, or induced color may fade with time, and these changes accelerate with increasing temperatures. In order to determine if this is significant in a given application, the following procedure shall be used. Characterize the post-irradiation behavior of each stock of dosimeters by determining specific absorbances at the analyzing wavelength at various times after irradiation at the temperature used. Choose the times to cover the range of post-irradiation measurement times anticipated under typical operational conditions. Keep each dosimeter sealed in its package until measurement; that is, for each set of readings, use a new set of freshly opened dosimeters and do not re-read a dosimeter that was opened and read earlier.

9.2.2 Document any post-irradiation changes.

9.2.3 If specific absorbances measured in accordance with 9.2.1 are found to vary significantly with post-irradiation storage time, then apply correction factors for such time-dependent variations, taking into account the calibration curve for that stock of dosimeters to minimize dosimetric errors under routine operational conditions.

9.2.4 This procedure shall be required only once for a given stock of dosimeters, for a given set of irradiation conditions.

9.3 *Other Factors*:

9.3.1 During the characterization, calibration, and use of the dosimetry system the effects (if any) of temperature, humidity, absorbed dose rate, incident energy spectrum, and background ultraviolet radiation on the dosimeter response shall be determined and taken into account.

NOTE 11—Information regarding the magnitude of such effects on the dosimetric measurements may be obtained from sources such as scientific literature (see Refs **1-22**), dosimeter manufacturers, distributors, and qualified testing organizations.

10. Application of Dosimetry System

10.1 Determine the number of dosimeters required for the measurement of absorbed dose on the basis of the dosimetric uncertainty acceptable in a given application. See ASTM Practice E 668 for guidance on determining this number.

10.2 Follow the procedures in accordance with 8.2-8.3.9, inclusive.

10.3 Determine the absorbed dose from $\bar{k}$ and the system calibration curve.

11. Documentation Requirements

11.1 Record the dosimeter manufacturer, type, and batch number (code).

11.2 Record or reference the date of calibration, calibration