



Standard Practice for Use of a Radiochromic Optical Waveguide Dosimetry System¹

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^{ε1} NOTE—Footnote 1 was editorially altered in June 1999.

1. Scope

1.1 This practice covers the handling, testing, and procedure for using a radiochromic optical waveguide dosimetry system to measure absorbed dose in materials irradiated by photons in terms of absorbed dose in water.

1.2 This practice applies to radiochromic optical waveguide dosimeters that can be used within part or all of the specified ranges as follows:

1.2.1 The absorbed dose range is from 1 to 10 000 Gy for photons.

1.2.2 The absorbed dose rate is from 0.001 to 1000 Gy/s.

1.2.3 The radiation energy range for photons is from 0.1 to 10 MeV.

1.2.4 The irradiation temperature range is from –78 to +60°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 Dosimetry²

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods³

E 178 Practice for Dealing with Outlying Observations³

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers⁴

E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation²

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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 14.01.

E 668 Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices²

E 925 Practice for the Periodic Calibration of Narrow Band-Pass Spectrophotometers⁵

E 958 Practice for Measuring Practical Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers⁵

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System²

E 1204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing²

E 1205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System²

E 1261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing²

E 1275 Practice for Use of a Radiochromic Film Dosimetry System²

E 1276 Practice for Use of a Polymethylmethacrylate Dosimetry System²

2.2 *International Commission on Radiation Units and Measurements (ICRU) Reports:*⁶

ICRU Report 14—Radiation Dosimetry: X-Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 50 MeV

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

ICRU Report 33—Radiation Quantities and Units

ICRU Report 34—The Dosimetry of Pulsed Radiation

3. Terminology

3.1 Definitions:

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

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

3.1.3 *dosimeter batch*—quantity of dosimeters made from a specific mass of material with uniform composition, fabricated

⁵ Annual Book of ASTM Standards, Vol 03.06.

⁶ Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, U.S.A.

in a single production run under controlled, consistent conditions and having a unique identification code.

3.1.4 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.

3.1.5 measurement quality assurance plan—a documented program for the measurement process that ensures 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.

3.1.6 net response, ΔR —the radiation-induced change in the relationship of measured absorbance at a specific wavelength determined by subtracting the pre-irradiation response, R_0 , from the post-irradiation response, R :

$$\Delta R = R - R_0 \quad (1)$$

where:

$$R = \frac{A_\lambda}{A_{\lambda_{\text{ref}}}} \quad (2)$$

$$R_0 = \left[\frac{A_\lambda}{A_{\lambda_{\text{ref}}}} \right]_0$$

where:

A_λ = optical absorbance at the analysis wavelength, λ , and

$A_{\lambda_{\text{ref}}}$ = optical absorbance at a reference wavelength, λ_{ref} .

A block diagram of an instrument capable of measuring R or R_0 is shown in Fig. 1.

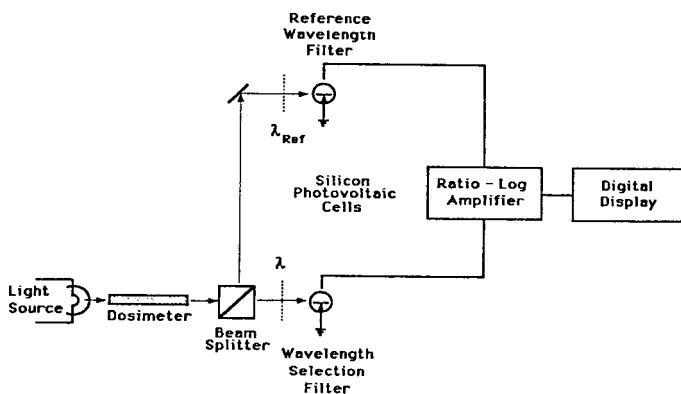


FIG. 1 Block Diagram of the Instrument Described in Section 5

3.1.7 optical waveguide—a device that contains an optical path at a high index of refraction relative to the material enclosing the optical path.

3.1.8 radiochromic optical waveguide—a specially prepared optical waveguide containing ingredients that undergo an ionizing radiation-induced change in photometric absorbance. This change in absorbance can be related to absorbed dose in water (1, 2).⁷

⁷ The boldface numbers in parentheses refer to the list of references at the end of this practice.

3.1.9 reference wavelength, λ_{ref} —the wavelength selected for comparison with the analysis wavelength. This wavelength is chosen to minimize effects associated with optical coupling and other geometric variations in the dosimeter.

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

3.2 Definitions or other terms used in this standard that pertain to radiation measurement and dosimetry may be found in Terminology Standard E 170. Definitions in E 170 are compatible with ICRU 33; that document, therefore, may be used as an alternative reference.

4. Significance and Use

4.1 The radiochromic optical waveguide dosimetry system provides a means of measuring absorbed dose in materials. Under the influence of ionizing radiation, chemical reactions take place in the radiochromic optical waveguide creating and/or modifying optical absorbance bands in the visible region of the spectrum. Optical response is determined at selected wavelengths using the equations in 3.1.6. Examples of appropriate wavelengths for the analysis for specific dosimetry systems are provided by their manufacturers and in Refs (1) through (5).

4.2 In the application of a specific dosimetry system, absorbed dose is determined by use of a calibration curve traceable to national standards.

4.3 The absorbed dose determined is usually specified in water. Absorbed dose in other materials may be determined by applying the conversion factors discussed in Guide E 1261.

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, and 34.

4.4 These dosimetry systems commonly are applied in the industrial radiation processing of a variety of products, for example, the sterilization of medical devices and radiation processing of foods (4-6).

5. Apparatus

5.1 The following shall be used to determine absorbed dose with radiochromic optical waveguide dosimetry systems:

5.1.1 Dosimeters—A batch or portion of a batch of radiochromic optical waveguide dosimeters.

5.1.2 Spectrophotometer or Photometer—An instrument, either a spectrophotometer equipped with a special dosimeter holder and associated coupling optics (7), or a modified photometer (Fig. 1), having documentation covering analysis wavelengths, accuracy of wavelength selection, absorbance determination, spectral bandwidth, and stray light rejection.

5.1.3 Holder, to position the dosimeter reproducibly in the measuring light beam.

6. Performance Check of Instrumentation

6.1 Check and document the performance of the photometer or spectrophotometer (see Practices E 275, E 925, E 958, and E 1026).

6.1.1 When using a photometer, check and document the accuracy of the absorbance scale at intervals not to exceed