



Standard Practice for Use of a Radiochromic Liquid Dosimetry System¹

This standard is issued under the fixed designation E 1540; 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.

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

1. Scope

1.1 This practice covers the preparation, handling, testing, and procedure for using radiochromic liquid dosimetry systems of radiochromic dye solutions held in sealed or capped containers (for example, ampoules, vials). It also covers the use of spectrophotometric or photometric readout equipment for measuring absorbed dose in materials irradiated by photons and electrons.

1.2 This practice applies to radiochromic liquid dosimeter solutions that can be used within part or all of the specified ranges as follows:

1.2.1 The absorbed dose range is from 0.5 to 40 000 Gy for photons and electrons.

1.2.2 The absorbed dose rate is from 10^{-3} to 10^{11} Gy/s.

1.2.3 The radiation energy range for photons is from 0.01 to 20 MeV.

1.2.4 The radiation energy range for electrons is from 0.01 to 20 MeV.

NOTE 1—Since electrons with energies less than 0.01 MeV may not penetrate the container of the solution, the solutions may be stirred in an open beaker with the electrons entering the solutions directly (1).²

1.2.5 The irradiation temperature range is from -40 to $+60^{\circ}\text{C}$.

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:

C 912 Practice for Designing a Process for Cleaning Technical Glasses³

¹ This practice is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.01 on Dosimetry for Radiation Processing.

Current edition, which includes substantial revisions to the last previous edition, was approved Jan. 10, 1998. Published May 1998. Originally published as E 1540 – 93. International Standard ISO 15565:1998(E) is identical to the last previous edition E 1540 – 93.

² The boldface numbers in parentheses refer to the list of references at the end of this practice.

³ Annual Book of ASTM Standards, Vol 15.02.

E 170 Terminology Relating to Radiation Measurements and Dosimetry⁴

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁵

E 178 Practice for Dealing with Outlying Observations⁵

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers⁶

E 456 Terminology Relating to Quality and Statistics⁵

E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation⁴

E 668 Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices⁴

E 925 Practice for the Calibration of Narrow Band-Pass Spectrophotometers⁶

E 958 Practice for Measuring Practical Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers⁶

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System⁴

E 1204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing⁴

E 1205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System⁴

E 1261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing⁴

E 1275 Practice for Use of a Radiochromic Film Dosimetry System⁴

E 1276 Practice for Use of a Polymethylmethacrylate Dosimetry System⁴

E 1310 Practice for Use of a Radiochromic Optical Waveguide Dosimetry System⁴

E 1400 Practice for Characterization and Performance of a High-Dose Gamma Radiation Dosimetry Calibration Laboratory⁴

E 1401 Practice for Use of a Dichromate Dosimetry System⁴

E 1431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing⁴

⁴ Annual Book of ASTM Standards, Vol 12.02.

⁵ Annual Book of ASTM Standards, Vol 14.02.

⁶ Annual Book of ASTM Standards, Vol 03.06.

E 1607 Practice for Use of the Alanine-EPR Dosimetry System⁴

E 1707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing⁴

2.2 *International Commission on Radiation Units and Measurements (ICRU) Reports:*⁷

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

ICRU Report 35—Radiation Dosimetry: Electron Beams with Energies between 1 and 50 MeV

ICRU Report 37—Stopping Powers for Electrons and Photons

ICRU Report 44—Tissue Substitutes in Radiation Dosimetry and Measurement

3. Terminology

3.1 Definitions:

3.1.1 *absorbance bandwidth*—spectral band used in a photometric instrument, such as a densitometer, for the measurement of optical absorbance or reflectance.

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

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

3.1.4 *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.

3.1.5 *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.

3.1.6 *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.

3.1.7 *molar linear absorption coefficient* (ϵ_m)—a constant relating the spectrophotometric absorbance, A_λ , of an optically absorbing molecular species at a given wavelength, λ , per unit pathlength, d , to the molar concentration, c , of that species in solution (2-4): $\epsilon_m = A_\lambda(d \times c)$. SI Unit: $\text{m}^2 \text{mol}^{-1}$.

3.1.8 *net absorbance*, ΔA —change in measured optical absorbance at a selected wavelength determined as the absolute difference between the pre-irradiation absorbance, A_0 , and the post-irradiation absorbance, A , as follows (2, 3): $\Delta A = |A - A_0|$.

3.1.9 *radiochromic liquid dosimeter*—specially prepared solution containing ingredients that undergo change in optical

absorbance under ionizing radiation. This change in optical absorbance can be related to absorbed dose in water.

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

3.1.11 *specific net absorbance* (Δk)—Net absorbance, ΔA , at a selected wavelength divided by the optical pathlength, d , through the dosimeter material as follows: $\Delta k = \Delta A/d$.

3.2 Definitions of 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 liquid dosimetry system provides a means of measuring absorbed dose in materials (5-7). Under the influence of ionizing radiation, chemical reactions take place in the radiochromic solution modifying the amplitudes of optical absorption bands (8-10). Absorbance values are measured at the selected wavelength(s) within these affected absorption bands (see also Guide E 1261 and Practices E 1205, E 1275, E 1276, E 1310, E 1400, and E 1401).

4.2 In the use of a specific dosimetry system, a calibration curve or response function relates the dosimeter's response to an absorbed dose traceable to a nationally or internationally recognized standard (11, 12).

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

NOTE 2—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, 35, and 37.

4.4 These dosimetry systems may be used in the industrial radiation processing of a variety of products, for example the sterilization of medical devices and radiation processing of foods (5, 7, 13).

4.5 The available dynamic range indicated in 1.2.1 is achieved by using a variety of radiochromic leuco dyes (Table 1) in a variety of solutions (Table 2).

4.6 The ingredients of the solutions, in particular the solvents, can be varied so as to simulate a number of materials in terms of the photon mass energy-absorption coefficients, (μ_{en}/ρ) , for X-rays and gamma-rays and electron mass collision stopping powers, $[(1/\rho) dE/dx]$, over a broad spectral energy range from 0.01 to 100 MeV (14). For special applications certain tissue-equivalent radiochromic solutions have been designed to simulate various materials and anatomical tissues, in terms of values of (μ_{en}/ρ) for photons and $[(1/\rho) dE/dx]$ for electrons (14) (see also ICRU Report 44). Tabulations of the values of (μ_{en}/ρ) for water (15), the anatomical tissues (15, 16), and three specially designed radiochromic solutions, for photons over the energy range from 0.01 to 20 MeV, and tabulations of the values of $[(1/\rho) dE/dx]$ (16) for water, the tissues and the radiochromic solutions for electrons over the energy range from 0.01 to 20 MeV are given in Refs (12-14). For additional information see Guide E 1261, Practice E 666, and ICRU Reports 14, 17, 35, 37, and 44.

⁷ Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, U.S.A.