Standard Practice for Use of a Radiochromic Liquid Dosimetry System[1]

This standard is issued under the fixed designation ISO/ASTM 51540; 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 the procedures for preparation, handling, testing, and 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°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:*[3]

C912 Practice for Designing a Process for Cleaning Technical Glasses

E170 Terminology Relating to Radiation Measurements and Dosimetry

E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers

E666 Practice for Calculating Absorbed Dose From Gamma or X Radiation

E668 Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices

E925 Practice for Monitoring the Calibration of Ultraviolet-Visible Spectrophotometers whose Spectral Bandwidth does not Exceed 2 nm

E958 Practice for Estimation of the Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers

E1026 Practice for Using the Fricke Dosimetry System

2.2 *ISO/ASTM Standards:*[3]

51261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing

51400 Practice for Characterization and Performance of a High-Dose Gamma Radiation Dosimetry Calibration Laboratory

51707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing

2.3 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[4]

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

---

[1] This practice is under the jurisdiction of ASTM Committee E61 on Radiation Processing and is the direct responsibility of Subcommittee E61.02. on , and is also under the jurisdiction of ISO/TC 85/WG 3.

Current edition approved March 21, 2012. Published November 2012. Originally published as E 1540 – 93. Last previous ASTM edition E 1540–98$^{\epsilon 1}$. ASTM E 1540–93 was adopted by ISO in 1998 with the intermediate designation ISO 15565:1998(E). The present International Standard ISO/ASTM 51540:2004(2012)(E) replaces ISO 15565 and is a reapproval of the last previous edition ISO/ASTM 51540:2004(E).

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

[3] For referenced ASTM and ISO/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.

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

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
ICRU Report 60 Fundamental Quantities and Units for Ionizing Radiation

3. Terminology

3.1 *Definitions:*

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

3.1.2 *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.

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

3.1.4 *measurement quality assurance plan*—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.

3.1.5 *molar linear absorption coefficient* (ε_m)—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**): $\varepsilon_m = A_\lambda/(d \times c)$. SI Unit: $m^2\ mol^{-1}$.

3.1.6 *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**): $\Delta A = |A - A_0|$.

3.1.7 *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.

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

3.1.9 *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 ASTM Terminology E170. Definitions in E170 are compatible with ICRU 60; 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 ISO/ASTM Guide 51261).

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 ISO/ASTM Guide 51261.

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 (**18**). 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 (**18**) (see also ICRU Report 44). Tabulations of the values of (μ_{en}/ρ) for water (**19**), the anatomical tissues (**17, 19**), and three specially designed radiochromic solutions, for photons over the energy range from 0.01 to 20 MeV, and tabulations of the values of $[(1/\rho)\ dE/dx]$ (**17**) 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, 13, 18**). For additional information see ISO/ASTM Guide 51261, ASTM Practice E666, and ICRU Reports 14, 17, 35, 37, and 44.

5. Apparatus

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

5.1.1 *Batch or Portion of a Batch of Radiochromic Liquid.*

5.1.2 *Spectrophotometer or Photometer,* having documentation covering analysis wavelengths, accuracy of wavelength selection, absorbance determination, analysis bandwidth, and stray light rejection. The spectrophotometer should be able to read visible spectrum absorbance values of up to 2 with an uncertainty of no more than ±1 %.

5.1.3 *Glass Cuvettes,* having optical windows and path lengths of 5 to 100 mm, depending on the dose range of interest and on the size of the dosimeter ampoule used for irradiation.