Designation: E2304 – 03 (Reapproved 2011)

# Standard Practice for Use of a LiF Photo-Fluorescent Film Dosimetry System[1]

This standard is issued under the fixed designation E2304; 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.

## 1. Scope

1.1 This practice covers the handling, testing, and procedure for using a lithium fluoride (LiF)-based photo-fluorescent film dosimetry system to measure absorbed dose (relative to water) in materials irradiated by photons or electrons. Other alkali halides that may also exhibit photofluorescence (for example, NaCl, NaF, and KCl) are not covered in this practice. Although various alkali halides have been used for dosimetry for years utilizing thermoluminescence, the use of photoluminescence is relatively new.

1.2 This practice applies to photo-fluorescent film dosimeters (referred hereafter as photo-fluorescent dosimeters) that can be used within part or all of the following ranges:

1.2.1 Absorbed dose range of $5 \times 10^{-2}$ to $3 \times 10^{2}$ kGy (**1-3**).[2]

1.2.2 Absorbed dose rate range of 0.3 to $2 \times 10^{4}$ Gy/s (**2-5**)).

1.2.3 Radiation energy range for photons of 0.05 to 10 MeV (**2**).

1.2.4 Radiation energy range for electrons of 0.1 to 10 MeV (**2**).

1.2.5 Radiation temperature range of -20 to +60°C (**6,7**).

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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]

E170 Terminology Relating to Radiation Measurements and Dosimetry

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

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

2.2 *ISO/ASTM Standards:*

51204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing

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

51431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing

51608 Practice for Dosimetry in an X-ray (Bremsstrahlung) Facility for Radiation Processing

51649 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies between 300 keV and 25 MeV

51702 Practice for Dosimetry in a Gamma Irradiation Facility for Radiation Processing

51707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing

51818 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies between 80 keV and 300 keV

51956 Practice for Thermoluminescence-Dosimetry (TLD) Systems 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

ICRU Report 34 The Dosimetry of Pulsed Radiation

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

ICRU Report 60 Fundamental Quantities and Units for Ionizing Radiation

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[1] This practice is under the jurisdiction of ASTM Committee E61 on Radiation Processingand is the direct responsibility of Subcommittee E61.02 on Dosimetry Systems.

Current edition approved Nov. 1, 2011. Published November 2011. Originally approved in 2003. Last previous edition approved in 2003 as E2304-03. DOI: 10.1520/E2304-03R11.

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

[3] For referenced 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 International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, USA.

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## 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 $kg^{-1}$). The mathematical relationship is the quotient of $d\bar{\varepsilon}$ by $dm$, where $d\bar{\varepsilon}$ is the mean incremental energy imparted by ionizing radiation to matter of incremental mass $dm$ (see ICRU 60).

$$D = \frac{d\bar{\varepsilon}}{dm}$$

3.1.1.1 *Discussion*—Absorbed dose is sometimes referred to simply as dose. For a photon source under conditions of charged particle-equilibrium, the absorbed dose, *D*, may be expressed as:

$$D = \varphi E \frac{\mu_{en}}{\rho}$$

where:

$\varphi$ = particle fluence ($m^{-2}$),
$E$ = energy of the ionizing radiation (J), and
$\mu_{en}/\rho$ = mass energy absorption coefficient ($m^2$ $kg^{-1}$).

If bremsstrahlung production within the specified material is negligible, the mass energy absorption coefficient ($\mu_{en}/\rho$) is equal to the mass energy transfer coefficient ($\mu_{tr}/\rho$), and absorbed dose is equal to kerma if, in addition, charged-particle equilibrium exists.

3.1.2 *alkali halide*—a binary compound consisting of a halogen (any of the five elements fluorine, chlorine, bromine, iodine, and astatine) and an alkali metal (for example, lithium, sodium, and potassium).

3.1.3 *analysis wavelength*—wavelength used in a spectrophotometric instrument to help determine a desired dosimetric quantity, for example, absorbed dose, by means of the measurement of optical absorbance, optical density, reflectance or luminescence.

3.1.4 *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.

3.1.5 *charged-particle equilibrium*—the condition that exists in an incremental volume within a material under irradiation if the kinetic energies and number of charged particles (of each type) entering the volume are equal to those leaving the volume.

3.1.6 *color center*—imperfections (for example, negative- or positive-ion vacancies) within the ionic lattice of compounds that have trapped electrons or electron holes. These centers, upon excitation by energy in the form of light or heat, can produce luminescence.

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 *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.

3.1.9 *electron equilibrium*—charged particle equilibrium for electrons.

3.1.10 *fluorescence*—one of the four main luminescence mechanisms. In many materials, it involves the liberated electrons falling back to the valence band—directly or via a relaxation state—to fill an electron hole, resulting in the release of a photon. In the case of alkali-halides the liberated electrons do not fall back to the valance band, but are excited to a higher state within the color center, and subsequently fall back to the center's ground state, resulting in the release of a photon.

3.1.11 *fluorescence signal, $E_f$*—the photometric reading by a spectrofluorimeter in terms of light intensity incident on the photodetector. Typically, the value measured is some quantity proportional to the standardized quantity, irradiance, $E_i$ (for example, volts or amperes per unit area of detector surface, V $cm^{-2}$ or A $cm^{-2}$).

3.1.12 *fluorescence standard*—a solid or liquid material that produces a fluorescence upon excitation, with an emitted radiance that is calibrated and made traceable to a recognized standard.

3.1.13 *fluorimeter*—instrument used to measure the amount of fluorescence signal, $E_f$, emitted from a sample upon excitation by an energy source (usually in the form of light).

3.1.14 *irradiance, $E_i$*—a radiometric term for the radiant flux that is incident upon a surface, having units of W $m^{-2}$. Also see *radiance*.

NOTE 1—The standard symbol for irradiance is *E*; however, for this document the subscript, *i*, was added to distinguish irradiance from energy of ionizing radiation (see 3.1.1) and fluorescence signal.

3.1.15 *luminescence*—photon emission from a solid or liquid phosphor material during, or after, exposure to a form of energy. The main luminescence mechanisms are fluorescence, phosphorescence, thermoluminescence, and photoluminescence.

3.1.16 *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.

3.1.17 *measurement traceability*—the ability to demonstrate 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.

3.1.18 *net fluorescence, $\Delta E_f$*—measured fluorescence signal, $E_f$, from an irradiated sample, subtracted by the pre-irradiation fluorescence, $E_o$, as follows:

$$\Delta E_f = E_f - E_o$$