



Standard Practice for Use of Thermoluminescence-Dosimetry (TLD) Systems for Radiation Processing¹

This standard is issued under the fixed designation E 1956; 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 procedures for the use of thermoluminescence dosimeters (TLDs) utilized as routine dosimeters to determine the absorbed dose in a material irradiated by ionizing radiation. Examples of materials useful as TLDs include LiF, CaF₂, CaSO₄, Li₂B₄O₇, and Al₂O₃. Although some elements of the procedures have broader application, the specific area of concern is radiation processing of materials such as blood products, food, and insects for sterile release programs. This practice is applicable to the measurement of absorbed dose in materials irradiated by gamma rays, X rays, and electrons. Source energies covered are from 0.1 to 50 MeV photons and electrons. The range of absorbed dose covered is approximately from 1 to 10⁵ Gy (10² to 10⁷ rad), and the range of absorbed dose rates is approximately from 10⁻² to 10¹⁰ Gy/s (1 to 10¹² rad/s). Absorbed dose and absorbed dose-rate measurements in materials subjected to neutron irradiation are not covered in this practice.

1.2 Procedures for the use of TLDs for determining absorbed dose in radiation-hardness testing of electronic devices are given in Practice E 668.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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:

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 456 Terminology Relating to Quality and Statistics³

E 668 Practice for Application of Thermoluminescence-

Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices²

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

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

E 1431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing²

E 1702 Practice for Dosimetry in a Gamma Irradiation Facility for Radiation Processing²

E 1707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing²

2.2 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 MeV⁴

ICRU Report 17— Radiation Dosimetry: X Rays Generated at Potentials of 5 to 150 kV⁴

ICRU Report 33— Radiation Quantities and Units⁴

ICRU Report 34— The Dosimetry of Pulsed Radiation⁴

3. Terminology

3.1 Definitions:

3.1.1 *absorbed dose, D*—Quantity of ionizing radiation energy imparted per unit mass of specified material. The SI unit of absorbed dose is the gray (Gy), where 1 gray is equivalent to the absorption of 1 J 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 energy imparted by ionizing radiation to the matter in a volume element and dm is the mass of matter in that volume element.

$$D = \frac{d\bar{\epsilon}}{dm} \quad (1)$$

3.1.1.1 *Discussion*—The discontinued unit of absorbed dose is the rad (1 rad = 100 erg/g = 0.01 Gy). 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:

$$D = \phi E \frac{\mu_{en}}{\rho} \quad (2)$$

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 approved June 10, 1998. Published September 1998.

² Annual Book of ASTM Standards, Vol 12.02.

³ Annual Book of ASTM Standards, Vol 14.02.

⁴ Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, USA.

where:

ϕ = particle fluence,
 E = energy of the ionizing radiation, and
 $\frac{\mu_{en}}{\rho}$ = mass energy absorption coefficient.

If bremsstrahlung production within the specified material is negligible, the mass energy absorption coefficient, μ_{en} , is equal to the mass energy transfer coefficient, μ_{tr} , and absorbed dose is equal to kerma.

3.1.2 *absorbed-dose rate*—the absorbed dose per unit time interval.

3.1.3 *annealing*—thermal treatment of a TLD prior to irradiation or prior to readout.

3.1.3.1 *Discussion*—Pre-irradiation annealing of TLDs is usually done to erase the effects of previous irradiation and to readjust the sensitivity of the phosphor; pre-readout annealing usually is done to reduce low-temperature TLD response.

3.1.4 *calibration conditions*—the normal environmental conditions prevailing during routine calibration irradiations such as the ambient temperature, humidity, and lighting.

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

3.1.6 *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.

3.1.7 *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 to determine absorbed dose, consisting of dosimeters, measurement instruments and their associated reference standards, and procedures for the system's use.

3.1.9 *electron equilibrium*—a condition that exists in a 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.

3.1.9.1 *Discussion*—Electron equilibrium is often referred to as charged-particle equilibrium (see Terminology E 170 and ICRU Report 33).

3.1.10 *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.

3.1.11 *measurement traceability*—the ability to demonstrate and document periodically that the measurement results from a particular measurement system are in agreement within acceptable limits of uncertainty with comparable measurement results

obtained with a nationally or internationally recognized standard.

3.1.12 *primary standard dosimeter*—dosimeter of the highest metrological quality, established and maintained as an absorbed dose standard by a national or international standards organization.

3.1.13 *process load*—a volume of material with a specified loading configuration irradiated as a single entity.

3.1.14 *quality assurance*—all systematic actions necessary to provide adequate confidence that a measurement is performed to a predefined level of quality.

3.1.15 *reference dose location*—a position that has a reproducible and documented relationship relative to the maximum or minimum absorbed-dose positions (see Practice E 1204).

3.1.16 *reference standard dosimeter*—dosimeter of high metrological quality, used as a standard to provide measurements traceable to, and consistent with, measurements made using primary standard dosimeters.

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.

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

3.1.21 *transfer standard dosimeter*—dosimeter, often a reference standard dosimeter, intended for transport between different locations for use as an intermediary to compare absorbed dose measurements.

3.1.22 *thermoluminescence dosimeter (TLD)*—a TL phosphor, alone, or incorporated in a material, used for determining the absorbed dose in materials. For example, the TL phosphor is sometimes incorporated in a TFE-fluorocarbon matrix.

3.1.23 *thermoluminescence dosimeter (TLD) reader*—an instrument used to measure the light emitted from a TLD consisting essentially of a heating element, a light-measuring device, and appropriate electronics.

3.1.24 *thermoluminescence dosimeter (TLD) response*—the measured light emitted by the TLD and read out during its heating cycle consisting of one of the following: (a) the total light output over the entire heating cycle, (b) a part of that total light output, or (c) the peak amplitude of the light output.

3.1.25 *thermoluminescence (TL) phosphor*—a material that stores, upon irradiation, a fraction of its absorbed dose in various excited energy states. When thermally stimulated, the material emits this stored energy in the form of photons in the ultraviolet, visible, and infrared regions.

3.1.26 *TLD preparation*—the procedure of cleaning, annealing, and encapsulating the TL phosphor prior to irradiation.