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Standard Practice for Using the Fricke Dosimetry System[1]

This standard is issued under the fixed designation 51026; 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.

ε[1] NOTE—References to ISO/ASTM standards were editorially updated in December 2024.

1. Scope

1.1 This practice covers the procedures for preparation, testing, and using the acidic aqueous ferrous ammonium sulfate solution dosimetry system to measure absorbed dose to water when exposed to ionizing radiation. The system consists of a dosimeter and appropriate analytical instrumentation. The system will be referred to as the Fricke dosimetry system. The Fricke dosimetry system may be used as either a reference standard dosimetry system or a routine dosimetry system.

1.2 This practice is one of a set of standards that provides recommendations for properly implementing dosimetry in radiation processing, and describes a means of achieving compliance with the requirements of ASTM Practice 52628 for the Fricke dosimetry system. It is intended to be read in conjunction with ASTM Practice 52628.

1.3 The practice describes the spectrophotometric analysis procedures for the Fricke dosimetry system.

1.4 This practice applies only to gamma radiation, X-radiation (bremsstrahlung), and high-energy electrons.

1.5 This practice applies provided the following are satisfied:

1.5.1 The absorbed dose range shall be from 20 Gy to 400 Gy (**1**).[2]

1.5.2 The absorbed dose rate does not exceed 10^6 Gy·s^{-1} (**2**).

1.5.3 For radioisotope gamma sources, the initial photon energy is greater than 0.6 MeV. For X-radiation (bremsstrahlung), the initial energy of the electrons used to produce the photons is equal to or greater than 2 MeV. For electron beams, the initial electron energy is greater than 8 MeV.

NOTE 1—The lower energy limits given are appropriate for a cylindrical dosimeter ampoule of 12 mm diameter. Corrections for displacement effects and dose gradient across the ampoule may be required for electron beams (**3**). The Fricke dosimetry system may be used at lower energies by employing thinner (in the beam direction) dosimeter containers (see ICRU Report 35).

1.5.4 The irradiation temperature of the dosimeter should be within the range of 10 °C to 60 °C.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced documents

2.1 *ASTM Standards:*[3]

C912 Practice for Designing a Process for Cleaning Technical Glasses

E178 Practice for Dealing With Outlying Observations

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

E3083 Terminology Relating to Radiation Processing: Dosimetry and Applications

[1] This practice is under the jurisdiction of ASTM Committee E61 on Radiation Processing and is the direct responsibility of Subcommittee E61.02 on Dosimetry Systems. Originally developed as a joint ASTM/ISO standard in conjunction with ISO/TC 85/WG 3.

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

[3] For referenced ASTM standards, visit the ASTM webiste, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

51261 Practice for Calibration of Routine Dosimetry Systems for Radiation Processing
51707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing
52628 Practice for Dosimetry in Radiation Processing

2.2 *ISO/IEC Standards:*[4]

ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories
ISO 12749-4 Nuclear energy, nuclear technologies, and radiological protection—Vocabulary—Part 4: Dosimetry for radiation processing

2.3 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[5]

ICRU Report 14 Radiation Dosimetry: X Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 50 MeV
ICRU Report 35 Radiation Dosimetry: Electrons with Initial Energies Between 1 and 50 MeV
ICRU Report 64 Dosimetry of High-Energy Photon Beams based on Standards of Absorbed Dose to Water
ICRU Report 80 Dosimetry Systems for Use in Radiation Processing
ICRU Report 85a Fundamental Quantities and Units for Ionizing Radiation

2.4 *Joint Committee for Guides in Metrology (JCGM) Reports:*[6]

JCGM 100:2008 GUM 1995, with minor corrections Evaluation of measurement data – Guide to the expression of uncertainty in measurement
JCGM 200:2012, VIM International vocabulary of metrology – Basic and general concepts and associated terms

2.5 *National Research Council Canada (NRCC):*[7]

PIRS-0815 The IRS Fricke Dosimetry System

3. Terminology

3.1 *Definitions:*

3.1.1 *approved calibration laboratory*—calibration laboratory that is a recognized national metrology institute or has been formally accredited to ISO/IEC 17025.

3.1.1.1 *Discussion*—A recognized national metrology institute or other calibration laboratory accredited to ISO/IEC 17025 should be used for irradiation of dosimeters or dose measurements for calibration in order to ensure traceability to a national or international standard.

3.1.2 *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:

$$\varepsilon_m = \frac{A_\lambda}{(d \times c)} \tag{1}$$

Unit: $m^2 \cdot mol^{-1}$

3.1.3 *radiation chemical yield (G(x))*—quotient of $n(x)$ by $\bar{\varepsilon}$, where $n(x)$ is the mean amount of a specified entity, x, produced, destroyed, or changed by the mean energy, $\bar{\varepsilon}$, imparted to the matter.

$$G(x) = \left(\frac{n(x)}{\bar{\varepsilon}}\right) \tag{2}$$

Unit: $mol \cdot J^{-1}$

3.1.4 *reference standard dosimetry system*—dosimetry system, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived.

3.1.5 *type I dosimeter*—dosimeter of high metrological quality, the response of which is affected by individual influence quantities in a way that is well defined and capable of expression in terms of independent correction factors.

3.2 Definitions of other terms used in this standard that pertain to radiation measurement and dosimetry may be found in ASTM Practice 52628. Other terms that pertain to radiation measurement and dosimetry may be found in ASTM Terminology E3083 and ISO Terminology ISO 12749-4. Where appropriate, definitions used in these standards have been derived from and are consistent with definitions in ICRU Report 85a and general metrological definitions given in the VIM.

4. Significance and use

4.1 The Fricke dosimetry system provides a reliable means for measurement of absorbed dose to water, based on a process of oxidation of ferrous ions to ferric ions in acidic aqueous solution by ionizing radiation (ICRU 80, PIRS-0815, (**4**)). In situations not requiring traceability to national standards, this system can be used for absolute determination of absorbed dose without calibration, as the radiation chemical yield of ferric ions is well characterized (see Appendix X3).

4.2 The dosimeter is an air-saturated solution of ferrous sulfate or ferrous ammonium sulfate that indicates absorbed dose by an increase in optical absorbance at a specified wavelength. A temperature-controlled calibrated spectrophotometer is used to measure the absorbance.

5. Effect of influence quantities

5.1 The Fricke dosimeter response (change in optical absorbance) to a given radiation dose is dependent on irradiation temperature and measurement temperature. Thus, corrections may have to be applied for changes to the radiation chemical yield (G) for irradiation temperature and to the molar linear absorption coefficient (ε) for measurement temperatures. Both $\varepsilon(Fe^{3+})$ and $G(Fe^{3+})$ increase with increase in temperature. The subscripts indicate the temperature of irradiation and measurement, as applicable. Both of the temperatures are in °C.

$$\varepsilon_{T_{meas}} = \varepsilon_{25}[1 + 0.0069\,(T_{meas} - 25)] \tag{3}$$

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from International Commission on Radiation Units and Measurements (ICRU), 7910 Woodmont Ave., Suite 400, Bethesda, MD 20841-3095, http://www.icru.org.

[6] Document produced by Working Group 1 of the Joint Committee for Guides in Metrology (JCGM/WG1). Available free of charge at the BIPM website (http://www.bipm.org).

[7] Available from the National Research Council, Ionizing Radiation Standards, Ottawa, Ontario. K1A 0R6.