Designation: ~~ISO/ASTM 51275 – 2013(E)~~ 51275 – 21

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

This standard is issued under the fixed designation ~~ISO/ASTM~~ 51275; 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 is a practice for using radiochromic film dosimetry systems to measure absorbed dose in materials irradiated by photons or electrons in terms of absorbed dose to water. Radiochromic film dosimetry systems are generally used as routine dosimetry systems.

1.2 The radiochromic film dosimeter is classified as a ~~Type~~type II dosimeter on the basis of the complex effect of influence ~~quantities. See ASTM Practice~~ quantities (see ISO/ASTM ~~E2628~~52628~~.~~).

1.3 This document 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~~ISO/ASTM ~~E2628~~52628 "Practice for Dosimetry in Radiation Processing" for a radiochromic film dosimetry system. It is intended to be read in conjunction with ~~ASTM~~ISO/ASTM ~~E2628~~52628.

1.4 This practice covers the use of radiochromic film dosimetry systems under the following conditions:

1.4.1 The absorbed dose range is 1 Gy to 150 kGy.

1.4.2 The absorbed dose rate is 1×10^{-2} to 1×10^{13} Gy·s^{-1} (**1-4**).[2]

1.4.3 The photon energy range is 0.1 to 50 MeV.

1.4.4 The electron energy range is 70 keV to 50 MeV.

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

1.6 *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.*

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

Current edition approved ~~April 9, 2013~~Oct. 1, 2021. Published ~~June 2013~~May 2024. Originally ~~published as ASTM E 1275–88. Last previous ASTM edition E 1275–98~~approved in 1988. Last previous edition approved~~ε1~~. ~~ASTM E 1275–93 was adopted by ISO in 1998 with the intermediate designation ISO 15557:1998(E). The present International Standard ISO/ASTM 51275:2013(E) replaces ISO 15557 and is a major revision of the last previous edition ISO/ASTM 51275:2004(E).~~ in 2013 as ISO/ASTM 51275:2013(E). DOI: 10.1520/51275-21.

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

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

~~E2628~~E3083 ~~Practice for Dosimetry in Radiation Processing~~Terminology Relating to Radiation Processing: Dosimetry and Applications

~~E2701 Guide for Performance Characterization of Dosimeters and Dosimetry Systems for Use in Radiation Processing~~

2.2 *ISO/ASTM Standards:*[3]

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

52701 Guide for Performance Characterization of Dosimeters and Dosimetry Systems for Use in Radiation Processing

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

ICRU Report 85a Fundamental Quantities and Units for Ionizing Radiation

ICRU Report 80 Dosimetry Systems for Use in Radiation Processing

2.4 *ISO/ASTM Standards:*[5]

12749-4 Nuclear energy – Vocabulary – Part 4: Dosimetry for radiation processing

2.5 *Joint Committee for Guides in Metrology (JCGM) Reports:*

JCGM 100:2008, GUM 1995, with minor corrections, Evaluation of measurement data – Guide to the Expression of Uncertainty in Measurement[6]

JCGM 200:2008, VIM, International vocabulary of metrology – Basis and general concepts and associated terms[7]

3. Terminology

3.1 *Definitions:*

~~3.1.1 *calibration curve*—expression of the relation between indication and corresponding measured quantity value. **(VIM)***~~

~~3.1.1.1 *Discussion*—~~

~~In radiation processing dosimetry standards, the term 'dosimeter response' is generally used rather than 'indication'.~~

~~3.1.2 *dosimeter*—device having a reproducible, measurable response to radiation that can be used to measure the absorbed dose in a given system.~~

3.1.1 *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.

3.1.2 ~~*dosimetry*~~*dosimeter response*—reproducible, quantifiable effect produced in the dosimeter by ionizing radiation.

3.1.2.1 *Discussion*—

For radiochromic film dosimeters, the absorbance, specific absorbance or specific net absorbance is the dosimeter response.

3.1.3 ~~*dosimetry*~~*dosimeter stock*—part of a dosimeter batch held by the user.

3.1.4 *measurement management system*—a set of interrelated or interacting elements necessary to achieve metrological confirmation and continual control of measurement processes.

3.1.5 *radiochromic film dosimeter*—specially prepared film containing ingredients that undergo change in optical absorbance under ionizing radiation, which can be related to absorbed dose to water.

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[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, USA.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

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

[7] Document produced by Working Group 2 of the Joint Committee for Guides in Metrology (JCGM/WG 2). Available free of charge at the BIPM website (http://www.bipm.org).

3.1.6 *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.

3.1.7 *response*—see *dosimeter response*.

3.1.8 *routine dosimetry system*—dosimetry system calibrated against a reference standard dosimetry system and used for routine absorbed dose measurements, including dose mapping and process monitoring.

3.1.9 *specific absorbance (k)*—optical absorbance, A_λ, at a selected wavelength λ, divided by the optical path length, *d*:

~~$k = A_\chi D$~~ (1)

$k = A_\chi / d$ (1)

3.1.10 *specific net absorbance ~~(Δk)~~ (Δk)*—net absorbance, ΔA_λ, at a selected wavelength, λ, divided by the optical pathlength, *d*, through the dosimeter material as follows:

~~$\Delta k = \Delta A_\chi D$~~ (2)

$\Delta k = \Delta A_\chi / d$ (2)

3.2 Definitions of other terms used in this practice that pertain to radiation measurement and dosimetry may be found in ISO/ASTM Practice 52628. Other terms that pertain to radiation measurement and dosimetry may be found in ASTM Terminology ~~E170~~E3083~~. Definitions~~ and ISO Terminology 12749-4. Where appropriate, definitions used in ~~E170 are compatible with~~ these standards have been derived from, and are consistent with definitions in ICRU Report 85a; ~~that document, therefore, may be used as an alternative reference.~~and general metrological definitions given in the VIM.

4. Significance and use

4.1 The radiochromic film dosimetry system provides a means for measuring absorbed dose based on radiation-induced change in color using spectrophotometers, densitometers or scanned images.

4.2 Radiochromic film dosimetry systems are commonly used in industrial radiation processing, for example in the sterilization of medical devices and the irradiation of foods.

5. Overview

5.1 Radiochromic film dosimeters are manufactured by various methods to produce freestanding or coated films, which are flexible and transparent. They are generally supplied as small squares, strips, or long rolls or sheets that can be cut into a convenient size for dosimetry purposes. The response of the dosimeters may be influenced by water content, irradiation temperature, post-irradiation time to measurement, and other potential influence quantities that need to be taken into account. Many commercially available dosimeters are supplied in light- and vapor-tight packages, which effectively protect against light and changes in ambient humidity. The dosimeters should be calibrated under irradiation conditions that are similar to those in which they will be used.

5.2 Ionizing radiation induces chemical reactions in the material, which create or enhance absorption bands in the visible or ultraviolet regions, or both, of the optical spectrum. Absorbance determined at appropriate wavelengths within these radiation-induced absorption bands is quantitatively related to the absorbed dose. ICRU Report 80 provides technical information and historical development of the radiochromic film dosimetry systems in current use.

5.3 The radiation-induced change in absorbance of the radiochromic film depends on the wavelength of the light which is used to make the measurement.

6. Influence quantities

6.1 Factors other than absorbed dose which influence the dosimeter response are referred to as influence quantities. ~~Examples of such factors are temperature and dose rate. See ASTM~~ (See ISO/ASTM Guide ~~E2701~~52701~~.~~) See Refs (**2-~~1~~416**) for examples of

the types and magnitudes of the effects. It is recommended to calibrate the dosimetry system under the conditions of use (in-situ calibration) in order to help to account for the influence quantities and reduce their associated uncertainty along with batch to batch variations. Examples of such factors are temperature, humidity, dose rate and dose fractionation.

NOTE 1—Due to the variety of radiochromic dosimeter types the manufacturer should be consulted for specific recommendations regarding influence quantities and their significance for dosimeter use, shipment and storage.

6.2 *Pre-Irradiation Conditions:*

6.2.1 *Dosimeter Conditioning and Packaging*—Dosimeters may be conditioned by the manufacturer to optimize water content in the film, and then sealed in vapor and light tight pouches to maintain that condition.

6.2.2 *Time since Manufacture*—The shelf-life of ~~some~~ the different types of radiochromic film dosimeters ~~has been shown to exceed nine years.~~ varies and the manufacturer should be contacted for recommended duration. However, it is recommended that users carry out performance verification of pre-irradiation absorbance and post-irradiation response stability over the useful life of the dosimeter batch.

6.2.3 *Temperature*—Exposure to extreme temperature during shipment and storage at the user's facility might affect dosimeter response. ~~The manufacturer should be consulted for specific recommendations for dosimeter shipment and storage.~~

6.2.4 *Relative Humidity*—Dosimeters may be packaged so they are not affected by environmental changes in humidity; dosimeters without protective packaging might be affected. ~~The manufacturer should be consulted for specific recommendations for dosimeter shipment and storage.~~

6.2.5 *Exposure to Light*—Dosimeters may be packaged so they are not affected by exposure to light; dosimeters without protective packaging might be affected. ~~The manufacturer should be consulted for specific recommendations for dosimeter shipment and storage.~~

6.3 *Conditions During Irradiation:*

6.3.1 *Irradiation Temperature*—Irradiation temperature is expected to influence dosimeter response. ~~It is recommended to calibrate the dosimetry system under the conditions of use (in-plant calibration) in order to mitigate the effect of temperature on dosimeter response.~~

6.3.2 *Absorbed-dose Rate*—Absorbed-dose rate might influence dosimeter response. ~~It is recommended to calibrate the dosimetry system under the conditions of use (in-plant calibration) in order to mitigate any possible effect of dose rate on dosimeter response.~~

6.3.3 *Dose Fractionation*—Dose fractionation might influence dosimeter response. ~~It is recommended to calibrate the dosimetry system under the conditions of use (in-plant calibration) in order to mitigate any possible effect of dose fractionation.~~

6.3.4 *Relative Humidity*—For some dosimeters, the amount of water in the dosimeter is known to influence its response. For dosimeters used outside manufacturer's sealed packaging, it is recommended to calibrate the dosimetry system under the conditions of use (in-plant calibration) in order to mitigate any possible effect of variations in the amount of water in the dosimeter and hence its response.

6.3.5 *Exposure to Light*—Dosimeters may be packaged so they are not affected by exposure to light; dosimeters without protective packaging might be affected.

6.3.6 *Radiation Energy*—The response of dosimeters has been demonstrated to be independent of energy. However, when electron energy is low enough to result in a dose gradient through the thickness of the dosimeter, difficulties in interpretation of the measured response may result (~~15~~17).

NOTE 2—At low energies the thickness of the packaging material might give rise to measurement errors.

6.4 *Post-Irradiation Conditions:*

6.4.1 *Time*—Dosimeters may take significant time for the absorbance to stabilize after irradiation (**10-12, ~~16 and 17~~18, 19**). A post

irradiation heat-treatment process may stabilize the absorbance sooner. Dosimeter manufacturer should be consulted for specific recommendation for post-irradiation heat treatment.

NOTE 3—The response of FWT-60 and B3 some film dosimeters can be stabilized by a post-irradiation heat treatment. Users should consult the manufacturer for specific recommendations but generally the packaging status and a temperature and timer interval are specified as part of a heat treatment procedure (for example, 55–65 °C for 15–30 min).

NOTE 4—It is the responsibility of the user to establish a post-irradiation treatment process, and to ensure that the same procedure is followed during calibration and during measurement.

6.4.2 *Temperature*—Storage temperature after irradiation might influence dosimeter response. Dosimeter manufacturer should be consulted for specific recommendation for storage of irradiated dosimeters.

6.4.3 *Relative Humidity*—Water content in dosimeter after irradiation might influence dosimeter response. Dosimeter manufacturer should be consulted for specific recommendation for storage of irradiated dosimeters.

6.4.4 *Exposure to Light*—Dosimeters may be packaged so they are not affected by exposure to light; dosimeters without protective packaging might be affected.

6.5 *Response Measurement Conditions:*

6.5.1 Requirements for post irradiation conditions apply to conditions of measurement.

NOTE 5—Light used for measurement of dosimeter response might contain a UV component that can affect dosimeter response.

7. Dosimetry system and its verification

7.1 *Components of the Radiochromic Film Dosimetry System*—The following are components of radiochromic film dosimetry systems:

7.1.1 *Radiochromic Film Dosimeters*—The film may be provided in bulk or in pouches of one or more dosimeters. A pouch provides humidity and light protection.

7.1.2 *Measurement Instruments*—For each instrument used to measure dosimeter response, determine and establish the specific measurement settings capable of providing highly reproducible results over the required dose range. For example, use the peak absorbance wavelength for a specific dosimeter to optimize measurement reproducibility. Some dosimeters may require use of an off-peak wavelength to extend the usable dose range. Examples of appropriate analysis wavelengths for specific dosimetry systems are provided by the manufacturer and in Refs (**3-10**, **16-18-21**). Depending on the specific dosimetry system, the response may be absorbance, change in absorbance, specific absorbance or specific net absorbance.

7.1.2.1 *Calibrated Spectrophotometer* (or an equivalent instrument), with appropriate traceable calibration standards.capable of measuring optical absorbance at the analysis wavelength and having documentation specifying analysis wavelength range, accuracy of wavelength selection and absorbance determination, spectral bandwidth, and stray light rejection.

NOTE 6—Select a spectrophotometer The selected spectrophotometer should be capable of satisfying specified precision and dose range requirements. For example, in thin film dosimetry, the spectral bandwidth setting mustshould be appropriate (for example, several nm) for a given dosimeter thickness in order to avoid introducing optical interference fringes that adversely affect measurement reproducibility and can severely limit the lower end of achievable dose range.

7.1.2.2 *Densitometer,* with appropriate traceable calibration standards.

7.1.2.3 *Film Image Scanner,* with appropriate traceable calibration standards.

7.1.3 *Dosimeter Holder,* to position the dosimeter reproducibly during the absorbance measurement process.

7.1.4 *Calibrated Thickness Gauge (Optional),* with appropriate calibration standards.

NOTE 7—Most users will elect not to implement an on-site thickness measurement capability due to the technical difficulty associated with performing

highly reproducible thickness measurements on soft surfaced film dosimeters. Instead, most users will either ignore thickness (treating it as a constant) or utilize the average thickness as stated by the manufacturer.

7.2 *Measurement Management System,* including verification of the dosimetry system calibration curve resulting from calibration according to ISO/ASTM Practice 51261, and the procedures for its use.

7.3 *Performance Verification of Instrumentation:*

7.3.1 At ~~prescribed time intervals, or in the event of suspected performance issues during periods of use, check measurements against their calibration standards.~~user-defined intervals based on risk-assessment, the performance of the spectrophotometer shall be verified, the result(s) documented, and the result(s) compared with the instrument specifications (see ASTM Practice E275).

7.3.1.1 Verify the accuracy of optical absorbance measurement at or near the analysis wavelength (at a minimum) over the full range of the absorbance scale utilized for measurement of the dosimeter, for example through the use of certified optical absorption filters.

7.3.1.2 Verify the wavelength accuracy at or near the analysis wavelength (at a minimum) using calibrated references.

7.3.1.3 Means of verifying wavelength calibration, for example, through the use of certified filters.

7.3.2 If used, at user-defined intervals based on risk-assessment, the calibration of the thickness gauge shall be verified, the result(s) documented, and the result(s) compared with the instrument specifications, for example through the use of certified thickness gauge blocks, exceeding the range of thicknesses encountered. The thickness gauge shall also be checked before, during, and, if considered appropriate, after use, to ensure reproducibility and absence of zero drift.

7.3.3 Implementation of a daily check program intended to verify instrument performance before and after measurement sessions is also recommended.

8. Incoming dosimeter stock assessment

8.1 A protocol shall be established for the purchase, receipt, acceptance and storage of dosimeters.

8.2 The user shall perform an incoming inspection and acceptance testing for each shipment of dosimeters received. Samples should be randomly selected from the incoming stock as is possible.

8.2.1 Verify and document details such as batch, quantity, date received, miscellaneous descriptions (such as average thickness) and status of any shipping controls (such as temperature device's indication of whether temperature limits may have been exceeded during shipping).

8.2.2 Perform random sampling per documented procedures to verify dosimeter and pouch integrity and, if appropriate, to determine average thickness and average pre-irradiation absorbance.

8.2.3 It is also recommended that the user conduct dosimeter response testing at or near the planned high, medium and low doses either to determine that the batch samples respond within expectation or to verify the batch response of a new stock shipment against the results obtained with samples from a prior ~~shipment.~~shipment (see ISO/ASTM 51261).

8.3 Retain sufficient dosimeters for additional investigations, for use during verification or for recalibration.

8.4 Store dosimeters according to the manufacturer's recommendations, or specific user determined practices.

9. Calibration

9.1 Prior to initial use of each batch of dosimeters, the dosimetry system shall be calibrated in accordance with ISO/ASTM Practice 51261, and the user's procedures, which specify details of the calibration and quality assurance requirements.

9.2 The user's dosimetry system calibration shall take into account the influence quantities associated with pre–irradiation, irradiation, and post-irradiation conditions applicable to the process in the user's facility (see Section 6).