INTERNATIONAL

Designation: ~~ISO/ASTM 51650 – 2013(E)~~ 51650 – 21

Standard Practice for Use of a Cellulose Triacetate Dosimetry System[1]

This standard is issued under the fixed designation ~~ISO/ASTM~~ 51650; 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 a cellulose triacetate (CTA) dosimetry system to measure absorbed dose in materials irradiated by photons or electrons in terms of absorbed dose to water. ~~The~~ CTA ~~dosimetry system is classified~~is used as a routine dosimetry ~~system.~~system or used for relative dose measurements (that is, non-traceable dose measurements).

1.2 The CTA dosimeter is classified as a type II dosimeter on the basis of the complex effect of influence quantities on its response (see ~~ASTM~~ISO/ASTM Practice ~~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 CTA dosimetry system. It is intended to be read in conjunction with ~~ASTM~~ISO/ASTM ~~E2628~~52628.

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

1.4.1 The absorbed dose range is 10 kGy to 300 kGy.

NOTE 1—The dosimeter film irradiated to doses exceeding 200 kGy becomes brittle to some degree and must be handled with care. This may limit the practical dose range depending on the type of testing and handling required.

1.4.2 The absorbed-dose rate range is 3 Gy/s to ~~4×10~~4 ×10^{10} ~~Gy/s~~Gy·s (**1**).[2]

1.4.3 The photon energy range is 0.1 to 50 MeV.

1.4.4 The electron energy range is 0.2 to 50 MeV.

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

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

[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~~, 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 1650–94 with title: Practice for Use of Cellulose Acetate Dosimetry Systems. ASTM E 1650–94 was adopted by ISO in 1998 with the intermediate designation ISO 15570:1998(E). The present Third Edition of International Standard ISO/ASTM 51650:2013(E) is a major revision of the Second Edition of ISO/ASTM 51650:2005(E).~~approved in 1994. Last previous edition approved in 2013 as ISO/ASTM 51650:2013(E). DOI: 10.1520/51650-21.

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

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]

E170 Terminology Relating to Radiation Measurements and Dosimetry

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

E2628E3083 Practice for Dosimetry in Radiation ProcessingTerminology 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

51818 Standard Specification for Synthetic Fiber Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

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 Standard:*

12749-4 Nuclear energy—Vocabulary—Part 4: Dosimetry for radiation processing[5]

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 *absorbed-dose mapping*—measurement of absorbed dose within an irradiated product to produce a one-, two- or three-dimensional distribution of absorbed dose, thus rendering a map of absorbed-dose values.

3.1.1.1 *Discussion*—

The CTA dosimeter strip with appropriate length provides the opportunity for high resolution measurement of dose distribution, such as depth dose distribution.

3.1.2 *absorbed-dose rate* ($\dot{D}$)—absorbed dose in a material per incremental time interval, i.e., the quotient of d*D* by d*t*. Also see E170. The SI unit is Gy s^{-1}. **(ICRU-60, 4.2.6)**

$$\dot{D} = dD/dt \quad (1)$$

3.1.2.1 *Discussion*—

(1) The absorbed-dose rate is often specified in terms of its average value over longer time intervals, for example, in units of Gy·min^{-1} or Gy·h^{-1}. *(2)* In gamma industrial irradiators, dose rate may be significantly different at different locations. *(3)* In electron-beam irradiators with pulsed or scanned beam, there are two types of dose rate: average value over several pulses (scans) and instantaneous value within a pulse (scan). These two values can be significantly different.

3.1.3 *calibration curve*—expression of the relation between indication and corresponding measured quantity value. **(VIM:2008)**

3.1.3.1 *Discussion*—

In radiation processing standards, the term "dosimeter response" is generally used for "indication".

[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).

3.1.1 *cellulose triacetate dosimeter*—piece of CTA film that, during exposure to ionizing radiation, exhibits a quantifiable change in specific net absorbance as a function of absorbed dose.

~~3.1.5 *dosimeter*—device that, when irradiated, exhibits a quantifiable change that can be related to absorbed dose in a given material using appropriate measurement instruments and procedures.~~

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

3.1.3.1 *Discussion*—

For CTA dosimeters, the ~~specific net absorbance is the dosimeter response.~~response value (indication) is obtained by measurement of the specific net absorbance.

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

~~3.1.9 *measurement management system*—set of interrelated or interacting elements necessary to achieve metrological confirmation and continual control of measurement processes.~~

~~3.1.10 *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.~~

~~3.1.11 *response*—see *dosimeter response*.~~

~~3.1.12 *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.~~

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

$$\Delta k = \Delta A_\lambda / d \quad (1)$$

~~3.1.14 Definitions of other terms used in this practice that pertain to radiation measurement and dosimetry may be found in ASTM Terminology E170. Definitions in E170 are compatible with ICRU Report 85a; that document, therefore, may be used as an alternative reference.~~

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 E3083 and ISO Terminology 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~~Use

4.1 The CTA dosimetry system provides a means for measuring absorbed dose based on a change in optical absorbance in the CTA dosimeter following exposure to ionizing radiation (~~2, 3~~-2-10).

4.2 CTA dosimetry systems are commonly used in industrial radiation processing, for example in the modification of polymers and sterilization of health care products.

4.3 CTA dosimeter film ~~is~~ can be particularly useful in absorbed dose mapping because it is available in a ~~strip format and if~~ reel of 100 m whereby the user can cut any length of strip for use. When the CTA film is measured using a strip measurement ~~device,~~ device with a narrow distance interval (for example, 2 mm), it can provide ~~a dose map with higher resolution than using discrete points.~~high resolution results in a linear direction.

4.4 CTA is used to measure relative dose such as depth dose profiles in electron beam and reference phantom tests to assess irradiator changes in gamma.

4.5 When CTA is used as a routine monitoring dosimeter the user must take into consideration the effects of the multiple influence quantities that can affect the result and use appropriate techniques, as discussed herein, for characterizing and mitigating such influences and understanding their contribution to measurement uncertainty. Without such effort the dosimetry system may not meet the user's requirements for dosimetric release of some types of products (for example, health care products).

5. Overview

5.1 CTA dosimeters are manufactured by casting cellulose triacetate with a plasticizer, triphenylphosphate, and solvents, for example, a methylene chloride–methanol mixture (**2, 7**).

5.2 The commercially available dosimeter film is in the format of 8 mm width and 100 m length rolled on a spool, which is described in the informative annex.

5.3 Ionizing radiation induces chemical reactions in CTA and the plasticizer, which create or enhance optical absorption bands in the ultraviolet regions of the electromagnetic spectrum. Optical absorbance at appropriate wavelengths within these radiation-induced absorption bands is quantitatively related to the absorbed dose. ICRU Report 80 provides information on the scientific basis and historical development of the CTA dosimetry systems in current use.

5.4 The difference between the specific net absorbance of un-irradiated and irradiated CTA dosimeter depends ~~significantly~~ on the analysis wavelength used to make the absorbance measurement. Typically, the manufacturer recommends the analysis wavelength that optimizes sensitivity and post-irradiation stability. The analysis wavelengths recommended for some commonly used systems are given in Table A1.1.

5.4.1 The user's choice of calibration method, analysis wavelength, spectral bandwidth, dose range of utilization, and usage procedures, including allowed ranges of influence quantity conditions, shall be documented.

6. Influence quantities

6.1 Factors other than absorbed dose which influence the dosimeter response are referred to as influence quantities. These influence quantities include those related to the dosimeter before, during, and after irradiation and those related to the dosimeter response measurements (see ~~ASTM~~ISO/ASTM Guide ~~E2701~~52701). Influence quantities affecting dosimeter response are discussed below.

6.2 *Pre-Irradiation Conditions:*

6.2.1 *Dosimeter Conditioning and Packaging*—The dosimeter may require conditioning and packaging, particularly for low dose rate ~~(gamma)~~ irradiation. See 6.3.4.

NOTE 2—Conditioning CTA film and packaging pieces of it in environmentally impermeable pouches under controlled relative humidity conditions will provide for the most consistent dosimeter ~~response, however the film is often used with no packaging.~~response.

6.2.2 *Time Since Manufacture*—The pre-irradiation absorbance increases ~~very~~ slowly with time ~~and depends on the access to air (oxygen).~~presumably due to oxidation on the surface of the film **(7, 11).** The pre-irradiation absorbance of the outer layer(s) of a roll of CTA film may, therefore, increase more than the inner layers; hence, it may be advisable to discard the outer layer(s) of the film. Measure the pre-irradiation absorbance before using the dosimeter. Alternatively, compare the pre-irradiation absorbance to the average value noted at the time of calibration to determine if there is any ~~significant~~ change that ~~should~~shall be taken into account.

NOTE 3—The pre-irradiation absorbance to be used in the calculation of specific net absorbance will either be the value as measured before irradiation by the user, or a user-determined average ~~pre-irradiation absorbance.~~value.

6.2.3 *Temperature*—Avoid exposure to temperatures outside the manufacturer's recommended ~~range to reduce the potential for~~

~~adverse effects on dosimeter response.~~range. The effects of low or high temperatures on the product for short or long durations have not been dutifully examined but the product is a chemical dosimeter and may have some inherent risks, as such. Therefore, store the product under stable temperature conditions such as that of an office or laboratory upon receipt and for the duration of the CTA film's shelf life. Any impact of temperatures during shipping and storage on the product must be taken into account during incoming stock receiving inspection (see Section 8) or the dosimeter calibration (see Section 9), or both.

6.2.4 *Relative Humidity*—~~There is no known effect on dosimeter response.~~It is good practice to store the film in a controlled environment prior to use. Research on this topic generally used unspecified controlled storage conditions. Otherwise, the user must characterize the effect of variable relative humidity storage conditions on the subsequent performance of the dosimeter.

6.2.5 *Exposure to Light*—The dosimeter is insensitive to ~~visible light;~~ UV and visible light from normal room lighting; however, exposure to ~~UV light may have an effect and should be characterized. Exposure to UV prior to irradiation may increase the pre-irradiation absorbance of the film, and depends on the intensity of the UV~~ direct sunlight results in an increase in absorbance (**7, 11**).

6.3 *Conditions During Irradiation:*

6.3.1 *Irradiation Temperature*—The dosimeter response is ~~affected by temperature, particularly at low dose rates, and this effect shall be characterized~~ directly correlated to temperature. The variation in dosimeter response from 20 °C to 40 °C is approximately +5 % while the variation from 0 °C to 65 °C is greater than +20 % (**~~12~~7, ~~11~~9-12~~, 9, 10~~**). Calibration of the film under the conditions of use is recommended to avoid creating a bias in the calibration function due to the irradiation temperature differences between calibration and routine use. However, temperature variation over longer time intervals (months) will lead to a seasonal effect. The amount of this effect is not fully understood and may vary with other influence quantities. Users shall account for this by including a component of uncertainty for temperature variation during irradiation in their uncertainty budget or by re-calibration.

6.3.2 *Absorbed-Dose Rate*—The dosimeter response is affected by the absorbed-dose ~~rate and this effect shall be characterized~~ rate. There is a large variation in response between low and high dose rates of irradiation over the entire absorbed dose range (**4, 7, 8, 9, 13, ~~14-4~~14~~, 7-9~~**). The user must select a calibration method that accounts for this fact (see Section 9) and should include a component of uncertainty for dose rate if the rate varies between calibration and routine use.

6.3.3 *Dose Fractionation*—The dosimeter response is affected by dose ~~fractionation and shall be characterized~~ given in fractions (multiple, separate irradiations) and the effect is greater in high dose rate processes (**14**). The user shall characterize the impact of fractionation on the accuracy of dose measurements or calibrate and use the dosimeter under specified fractionation conditions.

6.3.4 *Relative Humidity*—The dosimeter response is affected by relative ~~humidity,~~ humidity during irradiation, particularly at low dose rates and relative humidity ~~extremes. This effect shall be characterized~~ extremes (**~~12~~4, ~~11~~7, ~~4~~9, ~~7~~11, ~~9~~12**). The user may choose to control relative humidity during calibration and use by sealing the CTA film in impermeable packaging to mitigate this effect. The user shall characterize the effect and account for it as a component of measurement uncertainty.

6.3.5 *Exposure to Light*—The dosimeter is ~~insensitive to visible light, however, exposure to UV light may have an effect and should be characterized. Exposure to UV~~not affected by exposure to normal room lighting. Refer to 6.2.5 ~~during irradiation may increase the optical absorbance of the film, and likely depends on the intensity of the UV~~ for additional information (**7, 11**).

6.3.6 *Radiation Energy*—There is no known effect on dosimeter ~~response, however,~~response. However, the irradiation of 125 micron thick CTA film using electron energies below 300 keV can result in a dose gradient ~~through~~within the film. Refer to ISO/ASTM 51818 for more details on dosimetry considerations when using <300 keV electrons.

6.4 *Post-Irradiation Conditions:*

6.4.1 *Time*—The dosimeter response varies with the time interval between radiation exposure and dosimeter measurement (**4, 7, 10, 11, 12, 14~~, 11, 4, 10~~**). ~~This effect shall be characterized and the measurement~~ After high dose rate irradiation such as electron beam the absorbance might decrease 10 % or more during the first 20 min after irradiation and then increase slowly 3-5 % over the next 3 h. See Fig. A2.1 and Fig. A2.2 in Annex A2~~time standardized.~~. The absorbance increases approximately 6 % or more over 10 days of elapsed time after irradiation with less than 1 % contribution in the last 5 days. See Fig. A2.3 in Annex A2. After low dose rate irradiation using sources such as gamma or X-ray, the absorbance changes more slowly, increasing approximately 2 % after 2 h elapsed time. See Fig. A2.5 in Annex A2 (**7, 11**).

6.4.1.1 A procedure shall be established to control the allowable time interval between irradiation and measurement; for example, a desired measurement time after irradiation (for example, 2 h) with some prescribed allowance for variation (for example, ±15 min). The uncertainty of the measurement of absorbed dose due to the user's allowance for variation in time after irradiation shall be determined and included in the user's measurement uncertainty budget (see ISO/ASTM 51707 for details on uncertainty of measurement).

~~NOTE 3—The absorbance first decreases and then slowly increases with storage time longer than fifteen minutes after high dose-rate electron beam irradiation. The dosimeter response will become more stable about two hours after irradiation. Therefore, it is recommended that the absorbance of the dosimeter be measured at a constant time period, for example, two hours after irradiation (11, 4, 7).~~

6.4.2 *Temperature*—The ~~temperature of CTA film storage~~ storage temperature after irradiation does have an effect ~~and shall be characterized. The user may need to control the post-irradiation storage~~at various points over the time interval after electron beam irradiation. See Fig. A2.2 ~~temperature within~~and Fig. A2.4 ~~a~~in Annex A2~~defined range~~ (**7, 9, 11**). After irradiation, store the film in a stable environment.

6.4.3 *Conditioning Treatment*—No advantageous post-irradiation treatment ~~has been found~~ is available or recommended (**4**).

6.4.4 *Relative ~~Humidity—~~Humidity (RH)—*The rate of change of the post-irradiation absorbance ~~may be~~ is affected by relative humidity ~~and shall be characterized. The user may need to control the post-irradiation storage relative humidity within a defined range~~ but the effect is generally less than 1 % in the first 4 h (**~~12~~7, ~~11~~9, ~~7~~11, ~~9~~12**). After irradiation, store the film in a stable environment.

6.4.5 *Exposure to Light*—~~The dosimeter is insensitive to visible light, however,~~ If the film is exposed to UV light after the irradiation (such as while traveling on a conveyance system or during removal from the product or apparatus to which it was attached), minimize exposure to UV light ~~may have an effect and should be characterized. Exposure~~ and refer to 6.2.5~~UV after irradiation may increase the post-irradiation absorbance of the film, and likely depends on the intensity of the UV~~. Apply the same principles when considering any effect after irradiation.~~(11).~~

~~NOTE 4—The post-irradiation absorbance of the film has been shown to change over longer storage periods (greater than 24 hours) and is dependent on the temperature and relative humidity during post-irradiation storage. The user should characterize longer term effects and define storage conditions if measurements will be made outside of the time interval used during calibration of the dosimetry system (see 6.4.1) (11, 9).~~

6.5 *Response Measurement Conditions:*

6.5.1 *Exposure to Light*—~~The dosimeter is insensitive to visible light, however, exposure to UV light may have an effect and should be characterized. Exposure to UV after irradiation may increase the post-irradiation absorbance of the film, and likely depends on the intensity of~~ During measurement the film may or may not be exposed to UV light for periods of time depending on the user's measurement environment. Refer to 6.2.5~~the UV~~ and apply the same principles when considering any effect during measurement (**7, 11**).

6.5.2 *Temperature*—The temperature conditions used during routine measurement shall be consistent with the conditions during ~~calibration.~~calibration of the CTA film.

6.5.3 *Relative Humidity*—The relative humidity conditions used during routine measurement shall be consistent with the conditions during ~~calibration.~~calibration of the CTA film.

7. Dosimetry system and its verification

7.1 *Components of the CTA Dosimetry System*—The following are components of a CTA dosimetry system:

7.1.1 *Cellulose Triacetate Dosimeter Film.*

7.1.2 *~~Calibrated~~ Spectrophotometer* (or an equivalent instrument), capable of ~~determining~~measuring optical absorbance at the analysis wavelength and having documentation specifying the wavelength range, ~~accuracy of wavelength selection and absorbance determination, spectral bandwidth, and stray light rejection.~~wavelength accuracy, absorbance (photometric) accuracy, and spectral bandwidth.

~~7.1.2.1 Means of verifying optical absorbance, for example using certified optical absorption filters, covering more than the range of absorption encountered.~~