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# 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.

## 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 as a routine dosimetry system.

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 Practice E2628).

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 E2628 "Practice for Dosimetry in Radiation Processing" for a CTA dosimetry system. It is intended to be read in conjunction with ASTM E2628.

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.

1.4.2 The absorbed-dose rate range is 3 Gy/s to $4 \times 10^{10}$ 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 *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

E2628 Practice for Dosimetry in Radiation Processing

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

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 *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[5]

JCGM 200:2008, VIM, International vocabulary of metrology – Basis and general concepts and associated terms[6]

## 3. Terminology

3.1 *Definitions:*

[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 ISO/TC 85/WG 3.

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

[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] 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).

[6] 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).

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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".

3.1.4 *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.

3.1.6 *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.

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

3.1.7.1 *Discussion*—For CTA dosimeters, the specific net absorbance is the dosimeter response.

3.1.8 *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.

3.1.13 *specific net absorbance* ($\Delta k$)—net absorbance, $\Delta A_\lambda$, at a selected wavelength, $\lambda$, divided by the optical pathlength, $d$, through the dosimeter as follows:

$$\Delta k = \Delta A_\lambda / d \quad (2)$$

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.

## 4. Significance and 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**, **3-10**).

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 particularly useful in absorbed dose mapping because it is available in a strip format and if measured using a strip measurement device, it can provide a dose map with higher resolution than using discrete points.

## 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 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.

## 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 Guide E2701). Influence quantities affecting dosimeter response are discussed below.

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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 1—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.

6.2.2 *Time Since Manufacture*—The pre-irradiation absorbance increases very slowly with time and depends on the access to air (oxygen). 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 be taken into account.

NOTE 2—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.

6.2.3 *Temperature*—Avoid exposure to temperatures outside the manufacturer's recommended range to reduce the potential for adverse effects on dosimeter response.

6.2.4 *Relative Humidity*—There is no known effect on dosimeter response.

6.2.5 *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 prior to irradiation may increase the pre-irradiation absorbance of the film, and depends on the intensity of the UV (**11**).

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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 (**12**, **11**, **9**, **10**).

6.3.2 *Absorbed-Dose Rate*—The dosimeter response is affected by the absorbed-dose rate and this effect shall be characterized (**13**, **14-4**, **7-9**).

6.3.3 *Dose Fractionation*—The dosimeter response is affected by dose fractionation and shall be characterized (**14**).

6.3.4 *Relative Humidity*—The dosimeter response is affected by relative humidity, particularly at low dose rates and relative humidity extremes. This effect shall be characterized (**12**, **11**, **4**, **7**, **9**).

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 during irradiation may increase the optical absorbance of the film, and likely depends on the intensity of the UV (**11**).

6.3.6 *Radiation Energy*—There is no known effect on dosimeter response, however, the irradiation of 125 micron thick CTA film using electron energies below 300 keV can result in a dose gradient through the film.

6.4 *Post-Irradiation Conditions:*

6.4.1 *Time*—The dosimeter response varies with the time interval between radiation exposure and dosimeter measurement (**12**, **14**, **11**, **4**, **10**). This effect shall be characterized and the measurement time standardized.

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 after irradiation does have an effect and shall be characterized. The user may need to control the post-irradiation storage temperature within a defined range (**11**).

6.4.3 *Conditioning Treatment*—No advantageous post-irradiation treatment has been found (**4**).

6.4.4 *Relative Humidity*—The rate of change of the post-irradiation absorbance may be affected by relative humidity and shall be characterized. The user may need to control the post-irradiation storage relative humidity within a defined range (**12**, **11**, **7**, **9**).

6.4.5 *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 after irradiation may increase the post-irradiation absorbance of the film, and likely depends on the intensity of the UV (**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 the UV (**11**).

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

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

## 7. Dosimetry system

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 optical absorbance at the analysis wavelength and having documentation specifying wavelength range, accuracy of wavelength selection and absorbance determination, spectral bandwidth, and stray light rejection.

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

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