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An American National Standard

Standard Guide for Performance Characterization of Dosimeters and Dosimetry Systems for Use in Radiation Processing¹

This standard is issued under the fixed designation E2701; 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 guide provides guidance on determining the performance characteristics of dosimeters and dosimetry systems used in radiation processing.

1.2 This guide describes the influence quantities that might affect the performance of dosimeters and dosimetry systems and that should be considered during dosimeter/dosimetry system characterization.

1.3 Users of this guide are directed to existing standards and literature for procedures to determine the effects from individual influence quantities and from combinations of more than one influence quantity.

1.4 Guidance is provided regarding the roles of the manufacturers, suppliers, and users in the characterization of dosimeters and dosimetry systems.

1.5 This guide does not address how the dosimeter/dosimetry system characterization information is to be used in radiation processing applications or in the calibration of dosimetry systems.

NOTE 1—For guidance on the use of dosimeter/dosimetry system characterization information for the selection and use of a dosimetry system, the user is directed to Practice E2628.

NOTE 2—For guidance on the use of dosimeter/dosimetry system characterization information for dosimetry system calibration, the user is directed to ISO/ASTM Guide 51261.

1.6 *This guide 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:²

¹ This guide is under the jurisdiction of ASTM Committee E61 on Radiation Processing and is the direct responsibility of Subcommittee E61.01 on Dosimetry. Current edition approved July 15, 2009. Published September 2009. DOI: 10.1520/E2701-09.

² 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.

E170 Terminology Relating to Radiation Measurements and Dosimetry

E456 Terminology Relating to Quality and Statistics

E1026 Practice for Using the Fricke Reference-Standard Dosimetry System

E1325 Terminology Relating to Design of Experiments

E2628 Practice for Dosimetry in Radiation Processing

2.2 ISO/ASTM Standards:²

51205 Practice for Use of a Ceriic-Cerous Sulfate Dosimetry System

51261 Guide for the Selection and Calibration of Dosimetry Systems for Radiation Processing

51707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing

2.3 ISO Reports:³

GUM Guide to the Expression of Uncertainty in Measurements, 1995.

VIM International Vocabulary of Basic and General Terms in Metrology

2.4 International Commission on Radiation Units and Measurements (ICRU) Reports⁴

Report 60 Fundamental Quantities and Units for Ionizing Radiation

Report 80 Dosimetry Systems for Use in Radiation Processing

3. Terminology

3.1 Definitions:

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

VIM:2008

3.1.2 *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.

3.1.3 *dosimeter batch*—quantity of dosimeters made from a specific mass of material with uniform composition, fabricated

³ Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, USA.

⁴ Available from the International Organization for Standardization, 1 rue de Varembe, Case Postale 56, CH-1211, Geneva 20, Switzerland..

in a single production run under controlled, consistent conditions and having a unique identification code.

3.1.4 dosimeter/dosimetry system characterization—determination of performance characteristics, such as useful dose range, reproducibility and the effects of influence quantities, for a dosimeter/dosimetry system under defined test conditions.

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

3.1.5.1 Discussion—The dosimeter response value, obtained from one or more measurements, is used in the estimation of the derived absorbed dose. The response value may be obtained from such measurements as optical absorbance, thickness, mass, peak-to-peak distance in EPR spectra, or electropotential between solutions.

3.1.6 dosimetry system—system used for determining absorbed dose, consisting of dosimeters, measurement instruments and their associated reference standards, and procedures for the system's use.

3.1.7 influence quantity—quantity that is not the measurand but that affects the result of the measurement. **VIM:1993**

3.1.7.1 Discussion—In radiation processing dosimetry, this term includes temperature, relative humidity, time intervals, light, radiation energy, absorbed-dose rate, and other factors that might affect dosimeter response, as well as quantities associated with the measurement instrument.

3.1.8 quality system—documented organizational structure, responsibilities, procedures, processes and resources for implementing quality management.

3.2 Definitions of other terms used in this standard that pertain to radiation measurement and dosimetry may be found in Terminology **E170**. Definitions in **E170** are compatible with ICRU Report 60; this document, therefore, may be used as an alternative reference. Definitions of other terms used in this standard that pertain to statistics and design of experiments may be found in Terminologies **E456** and **E1325**, respectively.

4. Significance and Use

4.1 Ionizing radiation produces physical or chemical changes in many materials that can be measured and related to absorbed dose. Materials with radiation-induced changes that have been thoroughly studied can be used as dosimeters in radiation processing.

NOTE 3—The scientific basis for commonly used dosimetry systems and detailed descriptions of the radiation-induced interactions are given in ICRU Report 80.

4.2 Before a material can be considered for use as a dosimeter, certain characteristics related to manufacture and measurement of its response to ionizing radiation need to be considered, including:

4.2.1 the ability to manufacture batches of the material with evidence demonstrating a reproducible radiation-induced change,

4.2.2 the availability of instrumentation for measuring this change, and

4.2.3 the ability to take into account effects of influence quantities on the dosimeter response and on the measured absorbed-dose values.

4.3 Dosimeter/dosimetry system characterization is conducted to determine the performance characteristics for a dosimeter/dosimetry system related to its capability for measuring absorbed dose. The information obtained from dosimeter/dosimetry system characterization includes the reproducibility of the measured absorbed-dose value, the useful absorbed-dose range, effects of influence quantities, and the conditions under which the dosimeters can be calibrated and used effectively.

NOTE 4—When dosimetry systems are calibrated under the conditions of use, effects of influence quantities may be minimized or eliminated, because the effects can be accounted for or incorporated into the calibration method (see ISO/ASTM Guide 51261).

4.4 The influence quantities of importance might differ for different radiation processing applications and facilities. For references to standards describing different applications and facilities, see Practice **E2628**.

4.5 Classification of a dosimeter as a type I dosimeter or a type II dosimeter (see Practice **E2628**) is based on performance characteristics related to the effects of influence quantities obtained from dosimeter/dosimetry system characterization.

4.6 The dosimeter manufacturer or supplier is responsible for providing a product that meets the performance characteristics defined in product specifications, certificates of conformance, or similar types of documents. Dosimeter specifications should be developed based on dosimeter/dosimetry system characterization.

4.7 The user has the responsibility for ensuring that the dosimetry requirements for the specific applications are met and that dosimeter/dosimetry system characterization information has been considered in:

4.7.1 determining the suitability of the dosimeter or dosimetry system for the specific application (see Practice **E2628**),

4.7.2 selecting the calibration method (see ISO/ASTM Guide 51261),

4.7.3 establishing dosimetry system operational procedures (see respective dosimetry system practice listed in Practice **E2628**), and

4.7.4 estimating the uncertainty components in the measured dose values (see ISO/ASTM Guide 51707).

4.8 Dosimeter/dosimetry system characterization information provided by manufacturers or suppliers, or available in the literature, should be reviewed by the user to determine the tests that should be performed prior to the use of the dosimeter or dosimetry system. Information on performance characteristics should be verified before using.

5. Dosimeter/Dosimetry System Characterization

5.1 Performance Characteristics:

5.1.1 Some examples of performance characteristics of dosimeters/dosimetry systems that may affect the measurement of absorbed dose are given in **Table 1**.

5.2 Measurement Instruments:



TABLE 1 Examples of Performance Characteristics of Dosimeters/Dosimetry Systems

Performance Characteristic	Description
Absorbed-dose range	Range over which the dosimetry system can be used within a maximum specified uncertainty
Applicable radiation type and energy	X-radiation, gamma radiation, and electron beam
Effect of influence quantities	Effects from individual influence quantities (see Table 2) and from combinations of more than one influence quantity (see 6.6)
Uncertainty	Achievable maximum level of uncertainty
Spatial resolution	Spatial resolution may be limited by dosimeter size, volume or area over which measurement is taken

5.2.1 Prior to conducting performance characterization of the dosimeters, it is necessary to establish procedures for the operation of the measurement instruments.

5.2.2 Operating procedures should be developed to control and optimize the performance of all measurement instruments and auxiliary systems, including those used for measuring mass or thickness or used for a post irradiation heat treatment.

5.2.3 The instruments used in a given dosimetry system with specific dosimeters should be calibrated with evidence of traceability and be tested to provide evidence of their suitability for use with the dosimeters. This should include a determination of repeatability and reproducibility for the specific measurement methods to be used.

5.2.4 The influence on measurement values attributable to rounding error, short term instrument drift, etc. over the expected range of use should be determined.

5.2.5 The performance of accessories such as dosimeter holders or dosimeter positioning apparatus within the measurement instrument should be determined.

5.2.6 The supplier of the performance characterization information should provide information on all instrumentation used in the characterization, including relevant performance specifications for the measurement instruments and characterization results.

NOTE 5—Characterization results are specific to the measurement instruments and measurement parameters used for the tests. Results cannot be used with other measurement instruments without adequate data to support equivalency.

5.2.7 Information obtained during the measurement system development to determine optimum or recommended instruments, including precautions to avoid known sources of error, should be made available to potential users.

5.3 Characterization:

5.3.1 All dosimeter samples used in the characterization must be representative of dosimeters supplied by the manufacturer/distributor.

5.3.2 The performance of dosimeter/dosimetry system characterization should be conducted in accordance with an experimental design that can effectively assess both individual and combined effects of the influence quantities being tested.

5.3.3 For performance characterization, dosimeters should be irradiated in facilities that can provide highly reproducible dose rates and well-quantified values of influence quantities.

NOTE 6—When studying the effects of irradiation conditions such as temperature or relative humidity, the conditions experienced by the dosimeters must be known within established limits. Dosimeter temperatures should be monitored. Reliance should not be placed on monitoring

the air temperature and assuming that there is temperature equilibrium. Difference between dosimeter temperature and air temperature may be associated with dose and may introduce bias in the characterization results over the dose range. For studies on the effects of changes of relative humidity, the time required for the water and oxygen content of the dosimeters to reach equilibrium should be taken into account. It is necessary to validate controlled irradiation conditions to verify that specified conditions can be achieved.

5.3.4 An initial calibration curve may be obtained by irradiating dosimeters over a range of absorbed doses at defined conditions, for example, specified temperature, relative humidity, and absorbed dose rate, and by measuring dosimeter response under defined measurement conditions. The defined conditions for the irradiation should approximate the expected range of values to be encountered during use of the dosimetry system.

NOTE 7—A calibration curve may be developed using a relationship expressed by response = $f(\text{dose})$.

5.4 Characterization Information:

5.4.1 Information on dosimeter and dosimetry system characterization carried out by the dosimeter manufacturer or supplier should be documented and made available to potential users.

5.4.2 The user is responsible for the evaluation of the effect of influence quantities or combinations of influence quantities, or both, on the dosimetry system performance over the full range of its intended use.

6. Effect of Influence Quantities

6.1 Influence Quantities to be Considered:

6.1.1 All influence quantities that might affect absorbed-dose determination should be considered. These influence quantities include those related to the dosimeter before, during, and after irradiation and those related to the dosimeter response measurements. Table 2 gives examples of some of these influence quantities.

6.1.2 The influence quantities shown with an asterisk (*) in Table 2 can be controlled by packaging the dosimeter material under specific conditions of relative humidity in light-tight gas-impermeable pouches. When the packaging is essential for the performance of the dosimeter, the packaging and the dosimeter are sometimes collectively referred to as the dosimeter.

6.1.3 If only one influence quantity is suspected to have an effect on dosimeter performance over the range of dose, the individual effect can be studied by varying its value (see 6.2–6.5).