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Practice for use of calorimetric dosimetry systems for electron beam dose measurements and routine dosimetry system calibration

Pratique de l'utilisation des systèmes dosimétriques calorimétriques pour des mesures de dose délivrée par un faisceau d'électrons et pour l'étalonnage de dosimètres

Reference number
ISO/ASTM 51631:2013(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

ASTM International is one of the world's largest voluntary standards development organizations with global participation from affected stakeholders. ASTM technical committees follow rigorous due process balloting procedures.

A pilot project between ISO and ASTM International has been formed to develop and maintain a group of ISO/ASTM radiation processing dosimetry standards. Under this pilot project, ASTM Committee E61, Radiation Processing, is responsible for the development and maintenance of these dosimetry standards with unrestricted participation and input from appropriate ISO member bodies.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. Neither ISO nor ASTM International shall be held responsible for identifying any or all such patent rights.

International Standard ISO/ASTM 51631 was developed by ASTM Committee E61, Radiation Processing, through Subcommittee E61.02, Dosimetry Systems, and by Technical Committee ISO/TC 85, Nuclear energy, nuclear technologies and radiological protection.

An American National Standard

Standard Practice for Use of Calorimetric Dosimetry Systems for Electron Beam Dose Measurements and Routine Dosimetry System Calibration[1]

This standard is issued under the fixed designation ISO/ASTM 51631; 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 practice covers the preparation and use of semi-adiabatic calorimetric dosimetry systems for measurement of absorbed dose and for calibration of routine dosimetry systems when irradiated with electrons for radiation processing applications. The calorimeters are either transported by a conveyor past a scanned electron beam or are stationary in a broadened beam.

1.2 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 Practice E2628 for a calorimetric dosimetry system. It is intended to be read in conjunction with ASTM Practice E2628.

1.3 The calorimeters described in this practice are classified as Type II dosimeters on the basis of the complex effect of influence quantities. See ASTM Practice E2628.

1.4 This practice applies to electron beams in the energy range from 1.5 to 12 MeV.

1.5 The absorbed dose range depends on the absorbing material and the irradiation and measurement conditions. Minimum dose is approximately 100 Gy and maximum dose is approximately 50 kGy.

1.6 The average absorbed-dose rate range shall generally be greater than 10 $Gy \cdot s^{-1}$.

1.7 The temperature range for use of these calorimetric dosimetry systems depends on the thermal resistance of the materials, on the calibrated range of the temperature sensor, and on the sensitivity of the measurement device.

1.8 *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:*[2]

E170 Terminology Relating to Radiation Measurements and Dosimetry

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

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:*[2]

51261 Practice for Calibration of Routine Dosimetry Systems for Radiation Processing

51431 Practice for Dosimetry in Electron and X-Ray (Bremsstrahlung) Irradiation Facilities for Food Processing

51649 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies Between 300 keV and 25 MeV

51707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing

2.3 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[3]

ICRU Report 34 The Dosimetry of Pulsed Radiation

ICRU Report 35 Radiation Dosimetry: Electron Beams with Energies Between 1 and 50 MeV

ICRU Report 37 Stopping Powers for Electrons and Positrons

ICRU Report 44 Tissue Substitutes in Radiation Dosimetry and Measurements

ICRU Report 80 Dosimetry Systems for use in Radiation Processing

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[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.

Current edition approved Aug. 16, 2012. Published April 2013. Originally published as E 1631 – 94. ASTM E 1631 – 96 $^{\epsilon 1}$ was adopted by ISO in 1998 with the intermediate designation ISO 15568:1998(E). The present International Standard ISO/ASTM 51631:2013(E) replaces ISO 15568 and is a major revision of the last previous edition ISO/ASTM 51631–2003(E).

[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.

[3] Available from the Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, U.S.A.

ICRU Report 85a Fundamental Quantities and Units for Ionizing Radiation

2.4 *Joint Committee for Guides in Metrology (JCGM) Reports:*[4]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *primary-standard dosimetry system*—dosimetry system that is designated or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity.

3.1.2 *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.

3.1.3 *transfer standard dosimetry system*—dosimetry system used as an intermediary to calibrate other dosimetry systems.

3.1.4 *type II dosimeter*—dosimeter, the response of which is affected by influence quantities in a complex way that cannot practically be expressed in terms of independent correction factors.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adiabatic*—no heat exchange with the surroundings.

3.2.2 *calorimeter*—assembly consisting of calorimetric body (absorber), thermal insulation, and temperature sensor with wiring.

3.2.3 *calorimetric body*—mass of material absorbing radiation energy and whose temperature is measured.

3.2.4 *calorimetric dosimetry system*—dosimetry system consisting of calorimeter, measurement instruments and their associated reference standards, and procedures for the system's use.

3.2.5 *endothermic reaction*—chemical reaction that consumes energy.

3.2.6 *exothermic reaction*—chemical reaction that releases energy.

3.2.7 *heat defect (thermal defect)*—amount of energy released or consumed by chemical reactions caused by the absorption of radiation energy.

3.2.8 *specific heat capacity*—amount of energy required to raise 1 kg of material by the temperature of 1 K.

3.2.9 *thermistor*—electrical resistor with a well-defined relationship between resistance and temperature.

3.2.10 *thermocouple*—junction of two metals producing an electrical voltage with a well-defined relationship to junction temperature.

3.3 Definitions of other terms used in this standard 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 This practice is applicable to the use of calorimetric dosimetry systems for the measurement of absorbed dose in electron beams, the qualification of electron irradiation facilities, periodic checks of operating parameters of electron irradiation facilities, and calibration of other dosimetry systems in electron beams. Calorimetric dosimetry systems are most suitable for dose measurement at electron accelerators utilizing conveyor systems for transport of product during irradiation.

NOTE 1—For additional information on calorimetric dosimetry system operation and use, see ICRU Report 80. For additional information on the use of dosimetry in electron accelerator facilities, see ISO/ASTM Practices 51431 and 51649, and ICRU Reports 34 and 35, and Refs **(1-3)**.[5]

4.2 The calorimetric dosimetry systems described in this practice are not primary standard dosimetry systems. The calorimeters are classified as Type II dosimeters (ASTM E2628). They may be used as internal standards at an electron beam irradiation facility, including being used as transfer standard dosimetry systems for calibration of other dosimetry systems, or they may be used as routine dosimeters. The calorimetric dosimetry systems are calibrated by comparison with transfer-standard dosimeters.

4.3 The dose measurement is based on the measurement of the temperature rise in an absorber (calorimetric body) irradiated by an electron beam. Different absorbing materials are used, but the response is usually defined in terms of dose to water.

NOTE 2—The calorimetric bodies of the calorimeters described in this practice are made from low atomic number materials. The electron fluences within these calorimetric bodies are almost independent of energy when irradiated with electron beams of 1.5 MeV or higher, and the mass collision stopping powers are approximately the same for these materials.

4.4 The absorbed dose in other materials irradiated under equivalent conditions may be calculated. Procedures for making such calculations are given in ASTM Practices E666 and E668, and Ref **(1)**.

4.4.1 Calorimeters for use at industrial electron accelerators have been constructed using graphite, polystyrene or a Petri dish filled with water as the calorimetric body **(4-10)**. The thickness of the calorimetric body shall be less than the range of the electrons.

4.4.2 Polymeric materials other than polystyrene may also be used for calorimetric measurements. Polystyrene is used because it is known to be resistant to radiation **(11)** and because almost no exo- or endothermic reactions take place **(12)**.

5. Interferences

5.1 *Extrapolation*—The calorimetric dosimetry systems described in this practice are not adiabatic, because of the exchange of heat with the surroundings or within the calorimeter assembly. The maximum temperature reached by the

[4] 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).

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