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# Practice for using the Fricke dosimetry system

*Pratique pour l'utilisation du système dosimétrique de Fricke*

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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 project between ISO and ASTM International has been formed to develop and maintain a group of ISO/ASTM radiation processing dosimetry standards. Under this project, ASTM Commitee 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 51026 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.

This first edition cancels and replaces the ASTM E1026-13, which has been technically revised.


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An American National Standard

# Standard Practice for Using the Fricke Dosimetry System[1]

This standard is issued under the fixed designation ISO/ASTM 51026; 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 procedures for preparation, testing and using the acidic aqueous ferrous ammonium sulfate solution dosimetry system to measure absorbed dose to water when exposed to ionizing radiation. The system consists of a dosimeter and appropriate analytical instrumentation. The system will be referred to as the Fricke dosimetry system. The Fricke dosimetry system may be used as either a reference standard dosimetry system or a routine dosimetry system.

1.2 This practice 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 ISO/ASTM Practice 52628 for the Fricke dosimetry system. It is intended to be read in conjunction with ISO/ASTM Practice 52628.

1.3 The practice describes the spectrophotometric analysis procedures for the Fricke dosimetry system.

1.4 This practice applies only to gamma radiation, X-radiation (bremsstrahlung), and high-energy electrons.

1.5 This practice applies provided the following are satisfied:

1.5.1 The absorbed dose range shall be from 20 to 400 Gy (**1**).[2]

1.5.2 The absorbed-dose rate does not exceed $10^6$ Gy·s$^{-1}$ (**2**).

1.5.3 For radioisotope gamma sources, the initial photon energy is greater than 0.6 MeV. For X-radiation (bremsstrahlung), the initial energy of the electrons used to produce the photons is equal to or greater than 2 MeV. For electron beams, the initial electron energy is greater than 8 MeV.

NOTE 1—The lower energy limits given are appropriate for a cylindrical dosimeter ampoule of 12 mm diameter. Corrections for displacement effects and dose gradient across the ampoule may be required for electron beams (**3**). The Fricke dosimetry system may be used at lower energies by employing thinner (in the beam direction) dosimeter containers (see ICRU Report 35).

1.5.4 The irradiation temperature of the dosimeter should be within the range of 10 to 60°C.

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 practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced documents

2.1 *ASTM Standards:*[3]

C912 Practice for Designing a Process for Cleaning Technical Glasses

E170 Terminology Relating to Radiation Measurements and Dosimetry

E178 Practice for Dealing With Outlying Observations

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

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

E925 Practice for Monitoring the Calibration of Ultraviolet-Visible Spectrophotometers whose Spectral Bandwidth does not Exceed 2 nm

E958 Practice for Estimation of the Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers

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

2.3 *ISO/IEC Standard:*

ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories[4]

[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 that appear in parentheses refer to a bibliography at the end of this practice.

[3] For referenced ASTM and ISO/ASTM standards, visit the ASTM webiste, 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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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2.4 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[5]

ICRU Report 14 Radiation Dosimetry: X Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 50 MeV

ICRU Report 35 Radiation Dosimetry: Electrons with Initial Energies Between 1 and 50 MeV

ICRU Report 64 Dosimetry of High-Energy Photon Beams based on Standards of Absorbed Dose to Water

ICRU Report 80 Dosimetry Systems for Use in Radiation Processing

ICRU Report 85a Fundamental Quantities and Units for Ionizing Radiation

2.5 *Joint Committee for Guides in Metrology (JCGM) Reports:*[6]

JCGM 100:2008 GUM 1995 , with minor corrections, Evaluation of measurement data – Guide to the expression of uncertainty in measurement

2.6 *National Research Council Canada (NRCC):*

PIRS-0815 The IRS Fricke Dosimetry System[7]

## 3. Terminology

3.1 *Definitions:*

3.1.1 *approved laboratory*—laboratory that is a recognized national metrology institute; or has been formally accredited to ISO/IEC 17025; or has a quality system consistent with the requirements of ISO/IEC 17025.

3.1.1.1 *Discussion*—A recognized national metrology institute or other calibration laboratory accredited to ISO/IEC 17025 should be used in order to ensure traceability to a national or international standard. A calibration certificate provided by a laboratory not having formal recognition or accreditation will not necessarily be proof of traceability to a national or international standard.

3.1.2 *molar linear absorption coefficient ($\varepsilon_m$)*—a constant relating the spectrophotometric absorbance ($A_\lambda$) of an optically absorbing molecular species at a given wavelength ($\lambda$) per unit pathlength ($d$) to the molar concentration ($c$) of that species in solution:

$$\varepsilon_m = \frac{A_\lambda}{(d \times c)} \tag{1}$$

Unit: $m^2 \cdot mol^{-1}$

3.1.3 *radiation chemical yield (G(x))*—quotient of $n(x)$ by $\bar{\varepsilon}$, where $n(x)$ is the mean amount of a specified entity, $x$, produced, destroyed, or changed by the mean energy, $\bar{\varepsilon}$, imparted to the matter.

$$G(x) = \left(\frac{n(x)}{\bar{\varepsilon}}\right) \tag{2}$$

Unit: $mol \cdot J^{-1}$

3.1.4 *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.

3.1.5 *type I dosimeter*—dosimeter of high metrological quality, the response of which is affected by individual influence quantities in a well-defined way that can be expressed in terms of independent correction factors.

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 85a; that document, therefore, may be used as an alternative reference.

## 4. Significance and use

4.1 The Fricke dosimetry system provides a reliable means for measurement of absorbed dose to water, based on a process of oxidation of ferrous ions to ferric ions in acidic aqueous solution by ionizing radiation (ICRU 80, PIRS-0815,(**4**)). In situations not requiring traceability to national standards, this system can be used for absolute determination of absorbed dose without calibration, as the radiation chemical yield of ferric ions is well characterized (see Appendix X3).

4.2 The dosimeter is an air-saturated solution of ferrous sulfate or ferrous ammonium sulfate that indicates absorbed dose by an increase in optical absorbance at a specified wavelength. A temperature-controlled calibrated spectrophotometer is used to measure the absorbance.

## 5. Effect of influence quantities

5.1 The Fricke dosimeter response (change in optical absorbance) to a given radiation dose is dependent on irradiation temperature and measurement temperature. Thus, corrections may have to be applied for changes to the radiation chemical yield ($G$) for irradiation temperature and to the molar linear absorption coefficient ($\varepsilon$) for measurement temperatures. Both $\varepsilon(Fe^{3+})$ and $G(Fe^{3+})$ increase with increase in temperature. The subscripts indicate the temperature of irradiation and measurement, as applicable. Both of the temperatures are in °C.

$$\varepsilon_{T_{meas}} = \varepsilon_{25}[1 + 0.0069\,(T_{meas} - 25)] \tag{3}$$

$$G_{T_{irrad}} = G_{25}[1 + 0.0012\,(T_{irrad} - 25)] \tag{4}$$

5.2 The radiation chemical yield depends on the type and energy of the radiation employed and, in particular, changes significantly at low photon energies (**5**).

## 6. Interferences

6.1 The Fricke dosimeter response is extremely sensitive to impurities in the solution, particularly organic impurities. Even in trace quantities, impurities can cause a detectable change in the observed response. For high accuracy, organic materials shall not be used for any component in contact with the solution, unless it has been demonstrated that the materials do not affect the dosimeter response.

[5] Available from International Commission on Radiation Units and Measurements (ICRU), 7910 Woodmont Ave., Suite 400, Bethesda, MD 20841-3095, http://www.icru.org.

[6] Document produced by Working Group 1 of the Joint Committee for Guides in Metrology (JCGM/WG1). Available free of charge at the BIPM website (http://www.bipm.org).

[7] Available from the National Research Council, Ionizing Radiation Standards, Ottawa, Ontario. K1A 0R6.



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