

INTERNATIONAL
STANDARD

ISO/ASTM
51205

First edition
2002-03-15

**Practice for use of a ceric-cerous sulfate
dosimetry system**

Pratique de l'utilisation d'un système dosimétrique au sulfate
cérique-céreuse
iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO/ASTM 51205:2002

<https://standards.iteh.ai/catalog/standards/sist/ef3b8495-f19d-4596-b332-cd458246b0a5/iso-astm-51205-2002>



Reference number
ISO/ASTM 51205:2002(E)

© ISO/ASTM International 2002

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. Neither the ISO Central Secretariat nor ASTM International accepts any liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies and ASTM members. In the unlikely event that a problem relating to it is found, please inform the ISO Central Secretariat or ASTM International at the addresses given below.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO/ASTM 51205:2002](https://standards.iteh.ai/catalog/standards/sist/e3b8495-f19d-4596-b332-cd458246b0a5/iso-astm-51205-2002)

<https://standards.iteh.ai/catalog/standards/sist/e3b8495-f19d-4596-b332-cd458246b0a5/iso-astm-51205-2002>

© ISO/ASTM International 2002

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester. In the United States, such requests should be sent to ASTM International.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

ASTM International, 100 Barr Harbor Drive, PO Box C700,
West Conshohocken, PA 19428-2959, USA
Tel. +610 832 9634
Fax +610 832 9635
E-mail khooper@astm.org
Web www.astm.org

Printed in the United States

Contents

Page

1 Scope	1
2 Referenced documents	1
3 Terminology	2
4 Significance and use	2
5 Interferences	3
6 Apparatus	3
7 Reagents	3
8 Preparation of the dosimetric solution	3
9 Analytical instrument performance	4
10 Calibration of the dosimetry system	4
11 Application of dosimetry system	6
12 Minimum documentation requirements	7
13 Measurement uncertainty	7
14 Keywords	7
Annexes	7
Bibliography	11
Figure A1.1 Electrochemical cell	8

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO/ASTM 51205:2002

<https://standards.iteh.ai/catalog/standards/sist/e3b8495-f19d-4596-b332-cd458246b0a5/iso-astm-51205-2002>

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 Subcommittee E10.01, Dosimetry for 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 International Standard 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 51205 was developed by ASTM Committee E10, Nuclear Technology and Applications, through Subcommittee E10.01, and by Technical Committee ISO/TC 85, Nuclear Energy.

Annexes A1, A2 and A3 of this International Standard are for information only.



Standard Practice for Use of a Ceric-Cerous Sulfate Dosimetry System¹

This standard is issued under the fixed designation ISO/ASTM 51205; 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, testing, and procedure for using the ceric-cerous sulfate dosimetry system to measure absorbed dose in water when exposed to ionizing radiation. The system consists of a dosimeter and appropriate analytical instrumentation. For simplicity, the system will be referred to as the ceric-cerous system. It is classified as a reference standard dosimetry system (see ISO/ASTM Guide 51261). Ceric-cerous dosimeters are also used as transfer-standard dosimeters or routine dosimeters.

1.2 This practice describes both the spectrophotometric and the potentiometric readout procedures for the ceric-cerous systems.

1.3 This practice applies only to γ rays, X rays, and high energy electrons.

1.4 This practice applies provided the following are satisfied:

1.4.1 The absorbed-dose range shall be between 5×10^2 and 5×10^4 Gy (1).²

1.4.2 The absorbed-dose rate shall be less than 10^6 Gy/s (1).

1.4.3 For radionuclide gamma-ray sources, the initial photon energy shall be greater than 0.6 MeV. For bremsstrahlung photons, the initial energy of the electrons used to produce the bremsstrahlung photons shall be equal to or greater than 2 MeV. For electron beams, the initial electron energy shall be greater than 8 MeV.

NOTE 1—The lower energy limits are appropriate for a cylindrical dosimeter ampoule of 12-mm diameter. Corrections for dose gradients across an ampoule of that diameter or less are not required for photons, but may be required for electron beams (2). The ceric-cerous system may be used at lower energies by employing thinner (in the beam direction) dosimeter containers (see ICRU Report 35).

1.4.4 The irradiation temperature of the dosimeter shall be between 0 and 62°C (3).

NOTE 2—The temperature coefficient of dosimeter response is known only in this range. For use outside this range, the dosimetry system should be calibrated for the required range of irradiation temperatures.

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:

C 912 Practice for Designing a Process for Cleaning Technical Glasses³

D 941 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Lipkin Bicapillary Pycnometer⁴

D 1193 Specification for Reagent Water⁵

E 170 Terminology Relating to Radiation Measurements and Dosimetry⁶

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁷

E 178 Practice for Dealing with Outlying Observations⁷

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers⁸

E 456 Terminology Relating to Quality and Statistics⁷

E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation⁶

E 668 Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices⁶

E 925 Practice for the Periodic Calibration of Narrow Band-Pass Spectrophotometers⁸

E 958 Practice for Measuring Practical Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers⁸

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System⁶

2.2 ISO/ASTM Standards:

51261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing⁶

51400 Practice for Characterization and Performance of a High-Dose Gamma Radiation Dosimetry Calibration Laboratory⁶

51401 Practice for Use of a Dichromate Dosimetry System⁶

51607 Practice for Use of the Alanine-EPR Dosimetry System⁶

51707 Guide for Estimating Uncertainties in Dosimetry for

¹ This guide is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.01 on Dosimetry for Radiation Processing, and is also under the jurisdiction of ISO/TC 85/WG 3.

Current edition approved Jan. 22, 2002. Published March 15, 2002. Originally published as ASTM E 1205–88. Last previous ASTM edition E 1205–99. ASTM E 1205–93 was adopted by ISO in 1998 with the intermediate designation ISO 15555:1998(E). The present International Standard ISO/ASTM 51205:2002(E) is a revision of ISO 15555.

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

³ *Annual Book of ASTM Standards*, Vol 15.02.

⁴ Discontinued; see 1993 *Annual Book of ASTM Standards*, Vol 05.01.

⁵ *Annual Book of ASTM Standards*, Vol 11.01.

⁶ *Annual Book of ASTM Standards*, Vol 12.02.

⁷ *Annual Book of ASTM Standards*, Vol 14.02.

⁸ *Annual Book of ASTM Standards*, Vol 03.06.

Radiation Processing⁶2.3 *International Commission on Radiation Units and Measurements (ICRU) Reports.*⁹

ICRU Report 14 Radiation Dosimetry: X-Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 60 MeV

ICRU Report 34 The Dosimetry of Pulsed Radiation

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

ICRU Report 37 Stopping Powers for Electrons and Positrons

ICRU Report 60 Radiation Quantities and Units

3. Terminology

3.1 *Definitions:*

3.1.1 *absorbed dose, D*—quantity of ionizing radiation energy imparted per unit mass of a specified material. The SI unit of absorbed dose is the gray (Gy), where 1 Gy is equivalent to the absorption of 1 J/kg of the specified material (1 Gy = 1 J/kg). The mathematical relationship is the quotient of $d\bar{\epsilon}$ by dm , where $d\bar{\epsilon}$ is the mean incremental energy imparted by ionizing radiation to matter of incremental mass dm (see ICRU 60).

$$D = \frac{d\bar{\epsilon}}{dm} \quad (1)$$

3.1.1.1 *Discussion*—The discontinued unit for absorbed dose is the rad (1 rad = 100 erg/g = 0.01 Gy). Absorbed dose is sometimes referred to simply as dose. For a photon source under conditions of charged particle equilibrium, the absorbed dose, D , may be expressed as:

$$D = \phi \cdot E \cdot \frac{\mu_{en}}{\rho} \quad (2)$$

where:

 ϕ = particle fluence (particles/m²), E = energy of the ionizing radiation (J), and

μ_{en}/ρ = mass energy absorption coefficient (m²/kg). If bremsstrahlung production within the specified material is negligible, the mass energy absorption coefficient (μ_{en}/ρ) is equal to the mass energy transfer coefficient (μ_{tr}/ρ), and absorbed dose is equal to kerma if, in addition, charged particle equilibrium exists.

3.1.2 *calibration facility*—combination of an ionizing radiation source and its associated instrumentation that provides a uniform and reproducible absorbed dose, or absorbed-dose rate traceable to national or international standards at a specified location and within a specific material, and that may be used to derive the dosimetry system's response function or calibration curve.

3.1.3 *electropotential*—difference in potential, E , between irradiated and unirradiated solutions in an electrochemical cell, measured in millivolts.

3.1.4 *measurement quality assurance plan*—a documented program for the measurement process that ensures on a

continuing basis that the overall uncertainty meets the requirements of the specific application. This plan requires traceability to, and consistency with, nationally or internationally recognized standards.

3.1.5 *measurement traceability*—the ability to demonstrate by means of an unbroken chain of comparisons that a measurement is in agreement within acceptable limits of uncertainty with comparable nationally or internationally recognized standards.

3.1.6 *molar linear absorption coefficient, ϵ_m* —a constant relating the spectrophotometric absorbance, A_λ , of an optically absorbing molecular species at a given wavelength, λ , per unit pathlength, d , to the molar concentration, c , of that species in solution:

$$\epsilon_m = \frac{A_\lambda}{d \cdot c} \quad (3)$$

SI unit: m²mol⁻¹

3.1.6.1 *Discussion*—The measurement is sometimes expressed in units of L mol⁻¹ cm⁻¹.

3.1.7 *net absorbance, ΔA* —change in measured optical absorbance at a selected wavelength determined as the absolute difference between the pre-irradiation absorbance, A_o , and the post-irradiation absorbance, A , as follows:

$$\Delta A = |A - A_o| \quad (4)$$

3.1.8 *radiation chemical yield, $G(\chi)$* —the quotient of $n(\chi)$ by $\bar{\epsilon}$, where $n(\chi)$ is the mean amount of a specified entity, χ , produced, or changed by the mean energy, $\bar{\epsilon}$, imparted to the

matter. <https://standards.iteh.ai/catalog/standards/sist/ef3b8495-f19d-4596-b332-cd458246b0a5/iso-astm-51205-2002>

$$G(\chi) = \frac{n(\chi)}{\bar{\epsilon}} \quad (5)$$

SI unit: mol J⁻¹

3.1.9 *reference-standard dosimeter*—a dosimeter of high-metrological quality, used as a standard to provide measurements traceable to, and consistent with, measurements made using primary-standard dosimeters.

3.1.10 *transfer-standard dosimeter*—a dosimeter, often a reference-standard dosimeter suitable for transport between different locations, used to compare absorbed-dose measurements.

3.2 For definitions of other terms used in this practice that pertain to radiation measurement and dosimetry, refer to ASTM Terminology E 170. Definitions in ASTM Terminology E 170 are compatible with ICRU 60; that document, therefore, may be used as an alternative reference.

4. Significance and Use

4.1 The ceric-cerous system provides a reliable means for measuring absorbed dose in water. It is based on a process of reduction of ceric ions to cerous ions in acidic aqueous solution by ionizing radiation (1, 4).

4.2 The dosimeter is a solution of ceric sulfate and cerous sulfate in sulfuric acid in an appropriate container such as a flame-sealed glass ampoule. The solution indicates a level of absorbed dose by a change (decrease) in optical absorbance at a specified wavelength in the ultraviolet region, or a change (increase) in electropotential. A calibrated spectrophotometer is

⁹ Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, USA.



used to determine the change in absorbance and a potentiometer, with a specially designed cell, is used to determine the change in potential in millivolts.

4.3 The dosimeter response has a temperature dependence during irradiation that is approximately equal to -0.2% per degree Celsius between 0 and 62°C (3, 5, 6).

4.4 For calibration with photons, the ceric-cerous dosimeter shall be irradiated under conditions that approximate electron equilibrium.

4.5 The absorbed dose in other materials irradiated under equivalent conditions may be calculated. Procedures for making such calculations are given in ASTM Practices E 666 and E 668 and ISO/ASTM Guide 51261.

NOTE 3—For a comprehensive discussion of various dosimetry methods applicable to the radiation types and energies discussed in this practice, see ICRU Reports 14, 34, 35, and 37.

5. Interferences

5.1 The ceric-cerous dosimetric solution response is sensitive to impurities, particularly organic impurities. Even in trace quantities, impurities can cause a detectable change in the observed response (7). For high-accuracy results, organic materials shall not be used for any component in contact with the solution. The effect of trace impurities is minimized by the addition of cerous ions to the solution (8, 9).

5.2 Undesirable chemical changes in the dosimetric solution can occur if care is not taken during flame-sealing of the ampoules (see 8.7).

6. Apparatus

6.1 *Spectrophotometric Method*—For the analysis of the dosimetric solution, use a high-precision spectrophotometer capable of measuring absorbance values up to two with an uncertainty of no more than $\pm 1\%$ in the region from 254 to 320 nm. Use quartz cuvettes with 10-mm path length for spectrophotometric measurements of absorbance of the solution.

6.2 *Potentiometric Method*—Use an electrochemical cell, similar to that in Annex A1 (see Fig. A1.1). Measure the electromotive force across the cell with a high-precision digital potentiometer that is capable of measuring d-c potentials in the range from 1 to 100 mV within an uncertainty of $\pm 1\%$.

NOTE 4—As shown in Fig. A1.1, the electrochemical cell has two compartments separated by a porous junction, such as a glass frit, a ceramic or kaolin junction, or a fibreglass wick. The inner compartment is filled with unirradiated solution. The lower compartment is filled with solution transferred from an irradiated or unirradiated ampoule. The potential difference, E , generated between the platinum electrodes in the two compartments is measured by a digital potentiometer.

6.3 *Glassware*—Use borosilicate glass or equivalent chemically resistant glass to store the reagents and the prepared dosimetric solution. Clean all glassware, except ampoules,

using chromic acid solution or an equivalent cleaning agent (see ASTM Practice C 912). Rinse at least three times with double-distilled water. Dry thoroughly and store under conditions that will minimize exposure to dust.

6.4 *Glass Ampoules*—If required, clean glass ampoules in boiling double-distilled water. Rinse twice with double-distilled water and oven dry.

NOTE 5—The dosimetric ampoule normally used has a capacity of approximately 2 mL. Quick-break glass ampoules, or Type 1 glass colorbreak ampoules or equivalent containers, are commonly used. Commercially available ampoules have been found to give reproducible results without requiring additional cleaning.

7. Reagents

7.1 Analytical reagent grade (or better) chemicals shall be used for preparing all solutions.¹⁰

7.2 Use of double-distilled water from coupled all-glass and silica stills is recommended for high-range dosimeters. For low-range stock solutions, use triply-distilled water. Water purity is very important since it is the major component of the dosimetric solutions, and therefore may be the prime source of contamination. Use of deionized water is not recommended. Type III reagent water as specified in ASTM Specification D 1193 is considered to be of sufficient quality for use in preparing all solutions.

NOTE 6—Double-distilled water distilled from an alkaline potassium permanganate (KMnO_4) solution (2 g KMnO_4 plus 5 g sodium hydroxide (NaOH) pellets in 2 L of distilled water) has been found to be adequate for routine preparation of the dosimetric solution. High-purity water is commercially available from some suppliers. Such water labeled HPLC (high-pressure liquid chromatographic) grade is usually sufficiently free from organics to be used in this practice.

7.3 Do not store purified water used in this practice in plastic containers or in containers with plastic caps or plastic cap liners.

8. Preparation of the Dosimetric Solution

8.1 The recommended concentrations for the ceric-cerous dosimeter to measure absorbed doses from about 5 to 50 kGy (high-range dosimeter) are 0.015- M ceric sulfate [$\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$] and 0.015- M cerous sulfate [$\text{Ce}_2(\text{SO}_4)_3 \cdot 8\text{H}_2\text{O}$]. For measurement of absorbed doses from about 0.5 to 10 kGy (low-range dosimeter), the recommended concentrations are 0.003- M [$\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$] and 0.003- M [$\text{Ce}_2(\text{SO}_4)_3 \cdot 8\text{H}_2\text{O}$].

8.2 The dosimeters specified in 8.1 may be formulated from the following nominal stock solutions: (a) 0.4- M and 4- M sulfuric acid (H_2SO_4), (b) 0.1- M $\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$, and (c) 0.1- M $\text{Ce}_2(\text{SO}_4)_3 \cdot 8\text{H}_2\text{O}$. Procedures for preparing these solutions are given in Annex A2.

¹⁰ Reagent specifications are available from American Chemical Society, 1115 16th St., Northwest, Washington, DC 20036, USA.



8.3 Use the following equations to determine the volume in millilitres of each stock solution necessary to prepare 1 L of dosimetric solution:

$$\begin{array}{ll} \text{High Range} & \text{Low Range} \\ \frac{V_1}{1000} = \frac{0.015}{M_1} & \frac{V_1}{1000} = \frac{0.003}{M_1} \end{array} \quad (6)$$

$$\frac{V_2}{1000} = \frac{0.015}{M_2} \quad \frac{V_2}{1000} = \frac{0.003}{M_2} \quad (7)$$

$$\frac{V_3}{1000 - V_1} = \frac{0.4}{M_3} \quad \frac{V_3}{1000 - V_1} = \frac{0.4}{M_3} \quad (8)$$

$$V_4 = 1000 - V_1 - V_2 - V_3 \quad V_4 = 1000 - V_1 - V_2 - V_3 \quad (9)$$

where:

- V_1 = volume of nominal 0.1- M ceric-sulfate stock solution,
- V_2 = volume of nominal 0.1- M cerous-sulfate stock solution,
- V_3 = volume of nominal 4- M sulfuric-acid stock solution,
- V_4 = volume of distilled water,
- M_1 = actual molarity of the ceric-sulfate stock solution,
- M_2 = actual molarity of the cerous-sulfate stock solution, and
- M_3 = actual molarity of the nominal 4- M sulfuric-acid stock solution.

NOTE 7—If the nominal molarities of $M_1 = M_2 = 0.1$, and $M_3 = 4$ are assumed, then $V_1 = V_2 = 150$ mL for the high range and $V_1 = V_2 = 30$ mL for the low range; $V_3 = 85$ mL for the high range and $V_3 = 97$ mL for the low range. If the molarities of the various stock solutions are significantly different from the nominal values, then use Eq. 6.8 to determine the exact volumes. To prepare a volume of the dosimetric solution other than 1000 mL, the result of these equations should be multiplied by the ratio of the desired volume in millilitres to 1000 mL.

8.4 Determine all of the volumes given in 8.3 using a calibrated graduated cylinder that can be read to within ± 0.5 mL.

8.5 Transfer the volume of each component of the dosimetric solution into a 1-L or larger glass storage container. Rinse the graduated cylinder used for measuring V_1 , V_2 , and V_3 by using some portion of the distilled water of V_4 . Stopper the container and shake well. Before use, allow the dosimetric solution to stand for at least five days in the dark.

8.6 Quality control testing of the dosimetric solution prior to ampouling can be performed by quantifying some of the dosimetric solution parameters, such as ceric-ion concentration, cerous-ion concentration, ceric-ion molar linear absorption coefficient, radiation chemical yield for the cerous ion, and density. Procedures for performing these measurements are given in Annex A3. Alternatively, quality control testing can be performed following ampouling by comparing calibration data with data obtained from previous batches (see 10.4.2).

8.7 Prepare dosimeters by filling ampoules with ~ 2 mL of dosimetric solution. Take care not to contaminate the dosimetric solution with impurities. Exercise care in filling ampoules to avoid depositing solution in the ampoule neck. Subsequent heating during sealing may cause an undesirable chemical change in the dosimetric solution remaining inside the ampoule

neck. Flame seal the ampoules, exercising care to avoid heating the body of the ampoule during sealing.

8.8 Store dosimeters in a dark place at room temperature ($23 \pm 5^\circ\text{C}$).

9. Analytical Instrument Performance

9.1 Spectrophotometer Performance:

9.1.1 Check the wavelength scale of the spectrophotometer and establish its accuracy. The emission spectrum from a low-pressure mercury arc lamp can be used for this purpose. Such lamps may be obtained from the spectrophotometer manufacturer or other scientific laboratory instrument suppliers. Other appropriate wavelength standards are holmium-oxide filters and solutions. For more details see ASTM Practices E 275, E 925, and E 958.

NOTE 8—For example, holmium-oxide solutions in sealed cuvettes are available as certified wavelength standards (SRM 2034) for use in the wavelength region from 240 to 650 nm (10).

9.1.2 Check the accuracy of the photometric (absorbance) scale of the spectrophotometer. Certified absorbance standard filters or solutions are available for this purpose.

NOTE 9—Examples of absorbance standards are solutions of various concentrations, such as SRM 931d (11) and SRM 935 (12), and metal-on-quartz filters, such as SRM 2031 (13, 14).

9.1.3 Check the linearity of the absorbance scale of the spectrophotometer as a function of the ceric-ion concentration. This should be done at the peak of the absorbance spectrum for the ceric ion at 320 nm at a constant temperature, preferably 25°C . The standardized ceric-sulfate stock solution (0.1- M nominal in 0.4- M H_2SO_4), as described in A2.3, may be used for this measurement. The plot of measured absorbance, A , per unit path length versus molar concentration shall be linear. The slope of the line gives, ϵ_m , the molar linear absorption coefficient.

NOTE 10—A reference value for ϵ_m is $561 \text{ m}^2 \cdot \text{mol}^{-1} \pm 0.4\%$ at 320 nm (3).

9.2 Potentiometer and Electrochemical Cell Performance:

9.2.1 For the potentiometer method, correct performance can be demonstrated by showing that the readings of dosimeters given known absorbed doses are in agreement with the expected readings within the limits of the dosimetry system uncertainty (see Section 13).

NOTE 11—This method is only applicable for reference standard dosimetry systems where the long term stability of the response has been demonstrated and documented.

10. Calibration of the Dosimetry System

10.1 Prior to use, the dosimetry system shall be calibrated in accordance with the user's documented procedure that specifies details of the calibration process and quality assurance requirements. This calibration procedure shall be repeated at regular intervals to ensure that the accuracy of the absorbed dose measurement is maintained within required limits. Detailed calibration procedures are provided in ISO/ASTM Guide 51261.

10.2 *Calibration Irradiation of Dosimeters*—Irradiation is a critical component of the calibration of the dosimetry system.



Calibration irradiations shall be performed by irradiating the dosimeters using a calibration facility that provides an absorbed dose or an absorbed-dose rate having measurement traceability to nationally or internationally recognized standards.

10.2.1 For the spectrophotometric measurement, separate five dosimeters from the remainder of the batch and do not irradiate them. Use them in determining \bar{A}_0 (see 10.2.7).

10.2.2 Calibrate the dosimeters, using an irradiation facility that has a dose rate traceable to national standards and that meets the requirements specified in ISO/ASTM Practice 51400. Use a reference or transfer dosimetry system to establish this traceability (see ISO/ASTM Guide 51261 and ASTM Practice E 1026).

10.2.3 Specify the calibration dose in terms of absorbed dose in water (for example, see ASTM Practice E 1026).

10.2.4 Position the dosimeters in the calibration radiation field in a defined, reproducible location.

10.2.5 When using a gamma-ray source for calibration, surround the dosimeters with a sufficient amount of material to achieve approximate electron equilibrium conditions.

NOTE 12—The appropriate thickness of such material depends on the energy of the radiation (see ASTM Practices E 666 and E 668). For measurement of absorbed dose in water, use materials that have radiation absorption properties essentially equivalent to water. For example, for a ^{60}Co source, 3 to 5 mm of polystyrene (or equivalent polymeric material) should surround the dosimeter in all directions.

10.2.6 When using an electron beam for calibration, locate the dosimeters in a well characterized position within the radiation field.

10.2.7 Make the calibration field within the volume occupied by the dosimeter(s) as uniform as possible. The variation in dose rate within this volume should be within $\pm 1\%$.

10.2.8 Control or monitor the temperature of the dosimeters during irradiation. Calculate or measure the mean irradiation temperature of each set of dosimeters to an accuracy of $\pm 2^\circ\text{C}$ or better.

10.2.9 Calibrate each batch of dosimeters prior to routine use.

10.2.10 Use a set of at least five dosimeters for each absorbed dose value.

10.2.11 Irradiate these sets of dosimeters to at least five known dose values, covering the dose range from 5 to 50 kGy for the high-range dosimeter or seven known dose values covering the dose range from 0.5 to 10 kGy for the low-range dosimeter.

10.3 Spectrophotometric Measurement:

10.3.1 For spectrophotometric measurement, dilute high-range dosimeters by a factor of 100 and low-range dosimeters by a factor of 50.

10.3.2 Pipette 0.25 mL of high-range dosimetric solution or 0.5 mL of low-range dosimetric solution into a clean, dry 25-mL volumetric flask.

10.3.3 Rinse the pipette with 0.4-M H_2SO_4 into the flask and make up to volume with 0.4-M H_2SO_4 .

10.3.4 Stopper the 25-mL flask, and mix well.

10.3.5 Transfer an appropriate amount into a quartz spec-

trophotometric cuvette (sample cell) from the 25-mL volumetric flask.

10.3.6 Read the absorbance, A , in the spectrophotometer at 320 nm.

10.3.7 Calculate the mean absorbance of the unirradiated dosimeters, \bar{A}_0 (see 10.2.1). Calculate the net absorbance, ΔA , for each irradiated dosimeter by subtracting its absorbance, A , from \bar{A}_0 as follows:

$$\Delta A = \bar{A}_0 - A \quad (10)$$

10.4 Potentiometric Measurement:

10.4.1 Place contents of an unirradiated dosimeter (ampoule) into both compartments of the electrochemical cell. See Annex A1 for a description of the electrochemical cell.

10.4.2 Allow the unirradiated dosimetric solution to remain in the electrochemical cell for about 30 min in order to establish equilibrium across the porous junction. For a new batch of dosimeters, or if a cell has not been used for one or two days, unirradiated solution should be left in both compartments for at least 16 h to ensure equilibrium across the porous junction.

10.4.3 When the cell is being used for the first time, the filled cell should be left to stand for at least 24 h before making any measurements.

10.4.4 If the cell is not going to be used for more than three days, drain all solution from the cell. Rinse both the inner and outer compartments three times with distilled water, and allow the cell to air dry. Refer to 10.4.1 and 10.4.2 before reusing the cell.

10.4.5 Drain the inner compartment and refill it with the contents of another unirradiated dosimeter.

10.4.6 Connect the digital potentiometer across the cell. If the electropotential, E , is equal to zero within ± 0.2 mV, the cell is ready for use. Read at least three unirradiated dosimeters, and determine average value \bar{E}_0 .

10.4.7 Expel the unirradiated solution from the outer compartment and draw in the solution from each irradiated dosimeter (ampoule) in turn, starting with the lowest and proceeding to the highest absorbed dose. In each case, before measuring the potential difference for any particular dosimeter, rinse the cell by drawing in a little less than half of that dosimeter's solution in order to reduce the effects of the previous dosimeter. Expel the rinse solution into a waste container, and then draw in sufficient solution from that remaining in the dosimeter ampoule to fully cover the porous junction.

10.4.8 Read the electropotential, E , in millivolts, across the cell for each dosimeter after temperature equilibrium is established within the cell. Subtract the average electropotential, \bar{E}_0 , to determine ΔE , the net potential value. Measure the readout temperature near the electrochemical cell, and apply correction for this temperature.

NOTE 13—The electropotential, E , within the electrochemical cell, has a positive temperature coefficient of 0.33 % per $^\circ\text{C}$ between 20 and 30°C (4).

10.5 Analysis:

10.5.1 Prepare a calibration curve by plotting ΔA or ΔE values versus the absorbed dose, D . Determine a response