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Practice for use of a radiochromic liquid dosimetry system

Pratique de l'utilisation d'un système dosimétrique radiochromique liquide

Reference number
ISO 15565:1998(E)

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.

International Standard ISO 15565 was prepared by the American Society for Testing and Materials (ASTM) Subcommittee E10.01 (as E 1540-93) and was adopted, under a special "fast-track procedure", by Technical Committee ISO/TC 85, *Nuclear energy*, in parallel with its approval by the ISO member bodies.

A new ISO/TC 85 Working Group WG 3, *High-level dosimetry for radiation processing*, was formed to review the voting comments from the ISO "Fast-track procedure" and to maintain these standards. The USA holds the convenership of this working group.

International Standard ISO 15565 is one of 20 standards developed and published by ASTM. The 20 fast-tracked standards and their associated ASTM designations are listed below:

ISO Designation	ASTM Designation	Title
15554	E 1204-93	*Practice for dosimetry in gamma irradiation facilities for food processing*
15555	E 1205-93	*Practice for use of a ceric-cerous sulfate dosimetry system*
15556	E 1261-94	*Guide for selection and calibration of dosimetry systems for radiation processing*
15557	E 1275-93	*Practice for use of a radiochromic film dosimetry system*
15558	E 1276-96	*Practice for use of a polymethylmethacrylate dosimetry system*
15559	E 1310-94	*Practice for use of a radiochromic optical waveguide dosimetry system*
15560	E 1400-95a	*Practice for characterization and performance of a high-dose radiation dosimetry calibration laboratory*
15561	E 1401-96	*Practice for use of a dichromate dosimetry system*

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15562	E 1431-91	*Practice for dosimetry in electron and bremsstrahlung irradiation facilities for food processing*
15563	E 1538-93	*Practice for use of the ethanol-chlorobenzene dosimetry system*
15564	E 1539-93	*Guide for use of radiation-sensitive indicators*
15565	E 1540-93	*Practice for use of a radiochromic liquid dosimetry system*
15566	E 1607-94	*Practice for use of the alanine-EPR dosimetry system*
15567	E 1608-94	*Practice for dosimetry in an X-ray (bremsstrahlung) facility for radiation processing*
15568	E 1631-96	*Practice for use of calorimetric dosimetry systems for electron beam dose measurements and dosimeter calibrations*
15569	E 1649-94	*Practice for dosimetry in an electron-beam facility for radiation processing at energies between 300 keV and 25 MeV*
15570	E 1650-94	*Practice for use of cellulose acetate dosimetry system*
15571	E 1702-95	*Practice for dosimetry in a gamma irradiation facility for radiation processing*
15572	E 1707-95	*Guide for estimating uncertainties in dosimetry for radiation processing*
15573	E 1818-96	*Practice for dosimetry in an electron-beam facility for radiation processing at energies between 80 keV and 300 keV*

Designation: E 1540 – 93

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Standard Practice for Use of a Radiochromic Liquid Dosimetry System[1]

This standard is issued under the fixed designation E 1540; 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 practice covers the preparation, handling, testing, and procedure for using radiochromic liquid dosimetry systems of radiochromic dye solutions held in sealed or capped containers (for example, ampoules, vials) and the spectrophotometric or photometric readout equipment for measuring absorbed dose in materials irradiated by photons and electrons in terms of absorbed dose in water.

1.2 This practice applies to radiochromic liquid dosimeter solutions that can be used within part or all of the specified ranges as follows:

1.2.1 The absorbed dose range is from 0.5 to 40 000 Gy for photons and electrons.

1.2.2 The absorbed dose rate is from 10^{-3} to 10^{11} Gy/s.

1.2.3 The radiation energy range for photons is from 1 to 20 MeV.

1.2.4 The radiation energy range for electrons is from 0.01 to 20 MeV.

NOTE 1—Since low-energy electrons, such as 0.01 MeV, may not penetrate the container of the solution, the solutions may be used in a stirred open beaker with the electrons entering the solutions directly (1).[2]

1.2.5 The irradiation temperature range is from −40 to +60°C.

1.3 *This standard does not purport to address all of the safety problems, 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 Glasses[3]

E 170 Terminology Relating to Radiation Measurements and Dosimetry[4]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[5]

E 178 Practice for Dealing with Outlying Observations[5]

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers[6]

E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation[4]

E 668 Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices[4]

E 925 Practice for the Calibration of Narrow Band-Pass Spectrophotometers[6]

E 958 Practice for Measuring Practical Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers[6]

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System[4]

E 1204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing[4]

E 1205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System[4]

E 1261 Guide for the Selection and Application of Dosimetry Systems for Radiation Processing of Food[4]

E 1275 Practice for Use of a Radiochromic Film Dosimetry System[4]

E 1276 Practice for Use of a Polymethylmethacrylate Dosimetry System[4]

E 1310 Practice for Use of a Radiochromic Optical Waveguide Dosimetry System[4]

E 1400 Practice for Characterization and Performance of a High-Dose Gamma-Radiation Dosimetry Calibration Laboratory[4]

E 1401 Practice for Use of a Dichromate Dosimetry System[4]

E 1431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing[4]

2.2 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[7]

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

ICRU Report 17—Radiation Dosimetry: X-Rays Generated at Potentials of 5 to 150 kV

ICRU Report 33—Radiation Quantities and Units

ICRU Report 34—The Dosimetry of Pulsed Radiation

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

[1] This practice is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.01 on Dosimetry for Radiation Processing.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

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

[4] *Annual Book of ASTM Standards*, Vol 12.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 14.01.

[7] Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

ICRU Report 37—Stopping Powers for Electrons and Photons
ICRU Report 44—Tissue Substitutes in Radiation Dosimetry and Measurement

3. Terminology

3.1 *Definitions:*

3.1.1 *analysis wavelength*—wavelength used in a spectrophotometer or photometer for measuring optical absorbance in the dosimetric solution.

3.1.2 *batch*—a quantity of dosimetric solution in a sealed container or a number of sealed containers such as ampoules, vials, or cuvettes, each containing the same size aliquot from a large quantity of dosimetric solution of specific ingredients, with all ingredients and date of preparation being identified with a unique code.

3.1.3 *calibration curve*—the graphical or mathematical relationship between the net response and the absorbed dose for a given dosimetry system. The calibration curve can also serve as the response function.

3.1.4 *dosimetry system*—system used for determining absorbed dose, consisting of dosimeters, measurement instrumentation, the calibration curve, reference standards, and procedures for the system's use.

3.1.5 *measurement quality assurance plan*—a documented program for the measurement process that quantifies the total uncertainty of the measurements (both random and systematic error components). This plan shall demonstrate traceability to national standards, and shall show that the total uncertainty meets the requirements of the specific application.

3.1.6 *molar linear absorption coefficient*, (E_m)—quotient given by the relation from Beer's law as follows **(2)**:

$$E_m = \frac{A}{Md}$$

where:
A = absorbance at a specified wavelength,
M = molar concentration of the ion of interest, and
d = optical pathlength within the solution measured by the spectrophotometer (see ICRU Report 35).
Units: $m^2 \cdot mol^{-1}$.

DISCUSSION—This quantity is often referred to in the literature as the *molar extinction coefficient*.

3.1.7 *net absorbance*, ΔA—the difference between the optical absorbance of an unirradiated dosimetric solution or solid, A_0, and the optical absorbance of an irradiated dosimetric solution, A **(2, 3)**:

$$\Delta A = A - A_0 \text{ (for increasing absorbance)}$$
$$\Delta A = A_0 - A \text{ (for decreasing absorbance)}$$

3.1.8 *radiation chemical yield*, $G(x)$—the quotient of $n(x)$ by $\bar{e}$ where $n(x)$ is the statistical amount of substance of a specified entity x, produced, destroyed, or changed, and $\bar{e}$ is the mean energy imparted to the matter (see ICRU Report 33 and **(4)**).

$$G(x) = \frac{n(x)}{\bar{e}}$$

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

DISCUSSION—This quantity is often referred to as *G value*. The former special unit was $mol \cdot (100\ eV)^{-1}$.

3.1.9 *radiochromic liquid dosimeter*—specially prepared solution containing ingredients that undergo change in optical absorbance under ionizing radiation. This change in optical absorbance can be related to absorbed dose in water.

3.1.10 *specific net absorbance*, k—net absorbance, ΔA, at a selected wavelength(s) divided by the optical pathlength, d, through the dosimeter as follows:

$$k = \frac{\Delta A}{d}$$

3.2 Other appropriate terms may be found in Terminology E 170.

4. Significance and Use

4.1 The radiochromic liquid dosimetry system provides a means of measuring absorbed dose in materials **(5–7)**. Under the influence of ionizing radiation, chemical reactions take place in the radiochromic solution modifying the amplitudes of optical absorption bands **(8–10)**. Absorbance values are measured at the selected wavelength(s) within these radiation-induced absorption bands (see also Guide E 1261 and Practices E 1275, E 1276, E 1310 – 89, E 1204, E 1400, E 1401 and E 1431).

4.2 In the use of a specific dosimetry system, absorbed dose is evaluated by use of a calibration curve traceable to national standards **(11, 12)**.

4.3 The absorbed dose that is measured is usually specified in water. Absorbed dose in other materials may be evaluated by applying the conversion factors discussed in Guide E 1261.

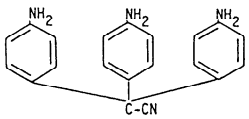
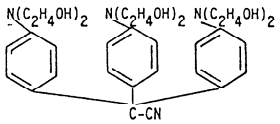
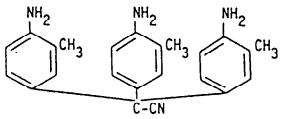
NOTE 2—For a comprehensive discussion of various dosimetry methods applicable to the radiation types and energies discussed in this practice, see ICRU Reports 14, 17, 34, 35, and 37.

4.4 These dosimetry systems may be used in the industrial radiation processing of a variety of products, for example the sterilization of medical devices and radiation processing of foods **(5, 7, 13)**.

4.5 The available dynamic range indicated in 1.2.1 is achieved by using a variety of radiochromic leuco dyes (Table 1) in a variety of solutions (Table 2).

4.6 The ingredients of the solutions, in particular the solvents, can be varied so as to simulate a number of materials in terms of the photon mass energy-absorption coefficients, (μ_{en}/ρ), for X-rays and gamma-rays and electron mass collision stopping powers, $[(1/\rho)\ dE/dx]$, over a broad spectral energy range from 0.01 to 100 MeV **(14)**. For special applications certain tissue-equivalent radiochromic solutions have been designed to simulate various materials and anatomical tissues, in terms of values of (μ_{en}/ρ) for photons and $[(1/\rho)\ dE/dx]$ for electrons **(14)** (see also ICRU Report 44). Tabulations of the values of (μ_{en}/ρ) for water **(15)**, the anatomical tissues **(15, 16)**, and three specially designed radiochromic solutions, for photons over the energy range from 0.01 to 20 MeV, and tabulations of the values of $[(1/\rho)\ dE/dx]$ **(16)** for water, the tissues and the radiochromic solutions for electrons over the energy range from 0.01 to 20 MeV are given in Refs **(12–14)**. For additional information see Guide E 1261, Practice E 666, and ICRU Reports 14, 17, 35, 37, and 44.

TABLE 1 Three Available Radiochromic Leuco Dyes, Their Formulae, Molecular Weight, and Values of ϵ_m and Color Index Numbers of the Parent Dyes (17, 19)

Radiochromic Leuco Dye (code)	Formula	Molecular Weight	Molar Linear Absorption Coefficient[A] (L mol^{-1} cm^{-1})	Color Index No.
Pararosaniline cyanide (PRC)		314.376	140 000 (λ = 550 nm)	42 500
Hexa(hydroxyethyl)pararosaniline cyanide (HHEVC)		578.715	100 000 (λ = 600 nm)	(none given)
New fuchsin cyanide (NFC)		356.455	130 000 (λ = 560 nm)	42 500

[A] These values of molar linear absorption coefficients are given in Ref **5** for 2-methoxyethanol solutions containing 17 mM acetic acid. The values may vary somewhat in other solvents and with other additives.

TABLE 2 Selected Radiochromic Solution Formulations and the Radiation Chemical Yields of Dye Cations in Solution

Radiochromic Leuco Dye (See Table 1)	Solution Formulation	Radiochromic Leuco Dye Concentration (mmol L^{-1})	Wavelength for Spectrophotometer, nm	G-Value, μmol J^{-1}	Nominal Dose Range, Gy	References
HHEVC	Dissolve in 2-methoxy ethanol containing 17 mmol L^{-1} acetic acid	5	599	0.025	10–1000	**5**
PRC	Dissolve in 2-methoxy ethanol containing 51 mmol L^{-1} acetic acid	5	549	0.033	10–3000	**1**
NFC	Dissolve in dimethyl sulfoxide containing 17 mmol L^{-1} acetic acid	0.1	554	0.0031	100–30 000	**17**
PRC	Dissolve in dimethyl sulfoxide containing 17 mmol L^{-1} acetic acid and 30 mmol L^{-1} nitrobenzene	5	554	0.0040	3–40 000	**11**
HHEVC	Dissolve in mixture of 85 % *n*-propanol and 15 % triethylphosphate (by volume), containing 34 mmol L^{-1} acetic acid, 500 parts-per-million nitrobenzoic acid and 10 % polyvinyl butyral (by weight)	2	605	0.0051	50–5000	**19**
NFC	Dissolve in mixture of 85 % triethylphosphate and 15 % dimethyl sulfoxide (by volume), containing 68 mM acetic acid, 500 parts-per-million nitrobenzoic acid and 10 % polyvinyl butyral (by weight)	2	557	0.0055	100–10 000	**12**
HHEVC	Dissolve in mixture of 85 % triethylphosphate and 15 % dimethyl sulfoxide (by volume), containing 68 mM acetic acid, 500 parts-per-million nitrobenzoic acid and 10 % polyvinyl butyral (by weight)	100	608	0.28	0.5–10	**16**

5. Apparatus

5.1 The following shall be used to determine absorbed dose with radiochromic liquid dosimetry systems:

5.1.1 *Batch or Portion of a Batch of Radiochromic Liquid.*

5.1.2 *Spectrophotometer or Photometer*, having documentation covering analysis wavelengths, accuracy of wavelength selection, absorbance determination, spectral bandwidth, and stray light rejection. The spectrophotometer should be able to read visible spectrum absorbance values of up to 2 with an uncertainty of no more than ±1 %.

5.1.3 *Glass Cuvettes* with optical windows and path lengths of 5 to 100 mm, depending on the dose range of interest and on the size of the dosimeter ampoule used for irradiations. Glass flow cells with parallel optical windows may be an alternative means of holding the solutions for spectrophotometry.

NOTE 3—Although control of temperature during spectrophotometry is not essential, as the temperature coefficient during spectrophotometric measurements is between 0 and −0.01 % per degree Celsius for the formulations in Table 2, the temperature during measurement should be within the temperature range from 20 to 30°C.

5.1.4 *Amber Glass Containers* for storing the solutions, with either glass, aluminum, or polyethylene liners for the lids. Use glass ampoules which are flame sealed for containing the solution during irradiation, or alternatively, glass vials with lids having aluminum or polyethylene liners, or disposable plastic vials, using only polymeric materials known to be resistant to any chemical effects by the solvents that are used. Another type of container for irradiation may be a cuvette equipped with a tightly closed cap. Any glass container should be cleaned with laboratory distilled water and detergent, rinsed with doubly distilled water and then with ethanol, dried at elevated temperature (>300°C) and

cooled to ambient laboratory temperature before being used to store the dosimetric solution. For more detail on cleaning glassware see Practice C 912. The solution should be stored at <30°C in the dark.

NOTE 4—The glass ampoules or vials for irradiation commonly have capacities of 2 to 5 mL. The glass is commonly amber to protect the solution from stray ultraviolet light.

6. Performance Check of Instrumentation

6.1 Check and document the performance of the photometer or spectrophotometer. (See Practices E 275, E 925, E 958, and E 1026.)

6.1.1 When using a photometer, estimate and document the precision and bias of the absorbance scale at intervals not to exceed one month during periods of use, or whenever there are indications of poor performance.

6.1.2 When using a spectrophotometer, estimate and document the precision and bias of the wavelength scale and absorbance scale at or near the selected analysis wavelength(s) at intervals not to exceed one month during periods of use, or whenever there are indications of poor performance.

6.1.3 Document the comparison of information obtained in 6.1.1 or 6.1.2 with the original instrument specification to verify adequate performance or take appropriate corrective action if required (see Practice E 275 and Section 9 of Practice E 1026).

7. Preparation of Dosimeters

7.1 *Solvents*—The solvents for dissolving radiochromic dye precursors include a number of liquid polar organic solvents, reagent grade or better. Examples include: ethanol, isopropanol, *n*-propanol, 2-methoxyethanol, 2-ethoxyethanol, *N,N*-dimethylformamide, dimethylsulfoxide, triethylphosphate **(1, 9–11, 14, 17–19)**. The choice of the solvent depends on which dosimeter formulation is needed for a given use (see 7.3). Use a solvent from a bottle which has not previously been opened if the solvent is likely to degrade after opening (for example, by forming peroxides).

7.2 *Dye Precursors*—The radiochromic dye precursor solutes for liquid dosimeters include the leuco dyes listed in Table 1.

7.3 *Formulations, Molar Linear Absorption Coefficients, and Radiation Chemical Yields*—A wide variety of combinations of solvents, radiochromic dyes, and selective additives are possible as indicated in the literature (see examples in references, where the radiation chemical yields, as listed in Table 2, are also documented). Table 1 lists nominal values of molar linear absorption coefficients, also derived from Refs **(17, 18)**. Table 2 lists several typical formulations, in terms of leuco dye solute, solvent and additive combination, radiation chemical yield, and literature reference.

7.4 *Preparation of Dosimeter Solutions*—Representative formulations for dissolution of the leuco dye solutes listed in Table 1 are given in Table 2, as typical liquid-radiochromic dosimeters.

7.4.1 These solutions are made at room temperature in a covered Ehrlenmeyer flask, using a magnetic stirring apparatus or other automatic stirring system. Stirring should be carried out long enough to assure complete dissolution. It is preferable in each case to add the additives (for example, acetic acid, nitrobenzoic acid, polyvinyl butyral) before adding the leuco dye for dissolution.

7.4.2 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 in the ampoule's neck. For the same reason, exercise care to avoid heating the body of the ampoule during sealing.

NOTE 5: **Caution**—Some leuco dye solutes and some solvents may be toxic or irritants on extended exposure. Appropriate precautions as recommended by the suppliers of ingredients shall be exercised.

NOTE 6—Some of the solutions listed in Table 2 are supplied as standard reference dosimeters, with well-characterized linear responses over specified dose ranges, irradiating temperature dependence values, radiation chemical yields, and linear molar absorption coefficients **(12, 18)**. Such solutions do not always need calibration and may be used with appropriate *G*-values and values of ϵ_m at an assigned spectrophotometric wavelength for the evaluation of absorbed dose in water (see **18** and Practice E 1026). When preparing solutions from ingredients as described in Table 2, each new solution should be calibrated since batches of commercially supplied leuco dyes may vary in quality **(5, 9, 11, 13)**.

8. Calibration of Dosimeters

8.1 *Irradiation:*

8.1.1 Separate five dosimeters from the batch and do not irradiate them. Use them in determining $\overline{A}_0$ (see 8.3.1).

8.1.2 Use a set of at least three dosimeters for each absorbed dose value.

8.1.3 Irradiate these sets of dosimeters to at least five known dose values covering the range of utilization. A minimum of five dose values per decade is recommended.

8.1.4 For calibrating the batch of dosimeters, use an irradiation facility that has a dose rate traceable to national standards and that meets the requirements specified in Practice E 1400. Use a reference or transfer dosimetry system to establish this traceability (see Guide E 1261, and Practices E 1026, E 1205 and E 1401).

8.1.5 Specify the calibration dose in terms of absorbed dose in water (for example, see Practices E 1026 and E 1205).

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

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

NOTE 7—For example, for a ^{60}Co gamma-ray source, 3 to 5 mm of polystyrene, or equivalent polymeric material, should surround the dosimeter in all directions.

8.1.8 When using an electron beam for the calibration, locate the dosimeters in a well-characterized position within the radiation field **(13, 20, 21)**.

8.1.9 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 ±1 %.

8.1.10 Control (or monitor) the temperature of the dosimeters during irradiation. Take into account any temperature variations that affect dosimeter response (that is, specific net absorbance). For the formulations in Table 2 the temperature dependence of dosimeter response during irradiation between 20 and 50°C is −0.2 % per degree Celsius **(13)**.

8.1.11 Calibrate each batch of dosimeters prior to routine

use, and at least once per year.

8.2 *Measurement:*

8.2.1 Depending on the radiochromic solution used (see Tables 1 and 2), set the spectrophotometer at the appropriate wavelength. Use a spectral bandwidth of no more than 1 nm.

8.2.2 Set the balance of the spectrophotometer to zero with only air (no cuvette or flow cell) in the light path(s).

8.2.3 Select a clean cuvette of a selected optical pathlength. Fill the cuvette with the solvent (or solvent mixture) used for the radiochromic solution being calibrated, and measure the absorbance (with air only in the reference beam of the spectrophotometer). Record this value ($A_{s,0}$).

NOTE 8—Choice of the cuvette pathlength depends on the maximum absorbance that can be measured accurately by the spectrophotometer and on the dose range and dosimetric solution's concentration chosen for a given calibration.

8.2.4 Empty the cuvette and rinse at least once with the dosimeter solution from an ampoule. Discard the rinse portion of the solution and fill the cuvette to the appropriate level with more solution from the same ampoule. Carefully wipe off any solution on the exterior surface of the cuvette and measure the absorbance. Repeat this procedure for all unirradiated and irradiated solutions.

NOTE 9—Inadequate rinsing of the cuvette can lead to errors due to solution carryover (cross-contamination). Techniques for minimizing this effect are discussed in Refs **13** and **17**.

8.2.5 Periodically during the measurement process, re-measure the absorbance of the solvent (or solvent mixture), A_s, first rinsing the cuvette with the solvent (or solvent mixture). Compare A_s with $A_{s,0}$ in order to detect and correct for any drift in the zero balance of the spectrophotometer or contamination of the cuvette.

8.2.6 Always check zero reading with only air in the light paths of the instrument.

8.3 *Analysis:*

8.3.1 Calculate the mean absorbance, $\overline{A_0}$ of the unirradiated dosimeters (see 8.1.1). Calculate the net absorbance, ΔA_i, for each irradiated dosimeter as follows:

$$\Delta A_i = A_i - A_0 \text{ (for increasing absorbance)}$$

$$\Delta A_i = A_0 - A_i \text{ (for decreasing absorbance)}$$

8.3.2 Prepare a calibration curve by plotting specific net absorbance versus absorbed dose. An example of a calibration curve is shown in Fig. 1. Absorption spectra for a series of absorbed doses are shown in Fig.2.

8.3.3 Fit the data by means of a least-squares method with an appropriate analytical form that provides a best fit to the data. The data for most radiochromic liquid solution dosimeters best fit either a linear regression or a second- or third-order polynomial regression.

8.3.4 Estimate the precision (random uncertainty) of the individual dosimeter readings of the A_0 values and A_i values at each dose either from the results of replicate measurements or from the statistics of the least-squares fit of the data. The precision, expressed as one standard deviation, should not exceed 0.005 absorbance unit, for an optical pathlength of 10 mm. Suspected data outliers should be tested and eliminated using statistical procedures such as those found in Practices E 177 and E 178.

9. Use of Dosimetry Systems

9.1 Use a minimum of two dosimeters for each dose measurement. The number of dosimeters required for the measurement of absorbed dose on or within a material is determined by the precision of the dosimetry system and the required precision associated with the use. Appendix X3 of Practice E 668 describes a statistical method for determining this number.

9.2 Use the irradiation and measurement procedures in accordance with 8.1.1, 8.1.5, 8.1.10, 8.2.1 through 8.2.5, 8.3.1, and 8.3.2

9.3 Evaluate the absorbed dose from the net absorbance values and the calibration curve.

9.4 Record the calculated absorbed dose values and all

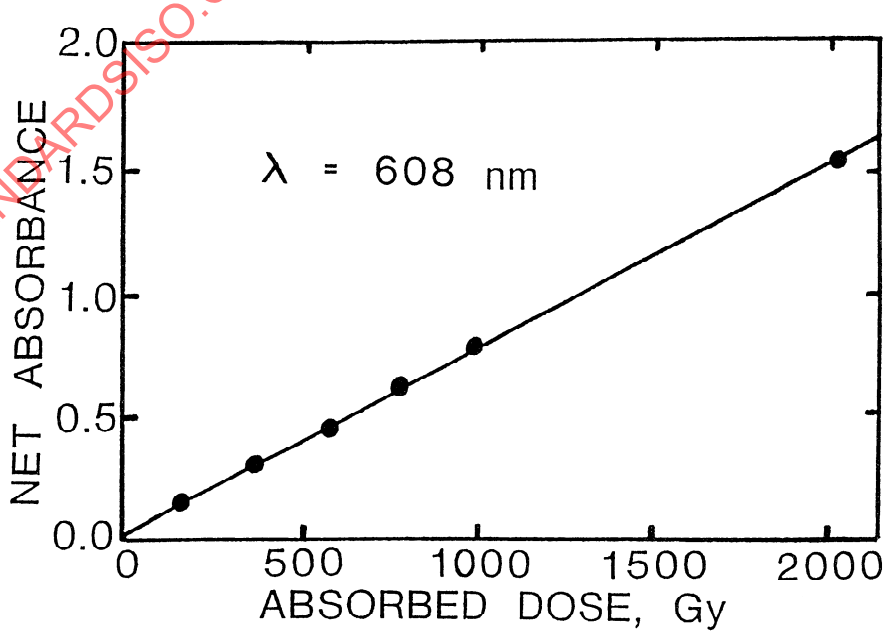


FIG. 1 Calibration Curve of a Typical Radiochromic Solution Dosimeter [2 mM HHEVC in a Mixture of 85 % TEP and 15 % DMSO (by Volume), Containing 68 mmol·L^{-1} Acetic Acid and 500 ppm Nitrobenzoic Acid and 10 % PVB (by Weight)], in Terms of $\Delta A_{608\ nm}$ Versus D (15)