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Standard Practice for Use of a Dichromate Dosimetry System[1]

This standard is issued under the fixed designation E 1401; 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.

ϵ^1 NOTE—Footnote 1 was editorially altered in June 1999.

1. Scope

1.1 This practice covers the preparation, testing, and procedure for using the acidic aqueous silver dichromate 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 dichromate system. It is classified as a reference standard dosimetry system (see Guide E 1261).

1.2 This practice describes the spectrophotometric analysis procedures for the dichromate system.

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

1.4 This practice applies provided the following conditions are satisfied:

1.4.1 The absorbed dose range is from 2×10^3 to 5×10^4 Gy.

1.4.2 The absorbed dose rate does not exceed 600 Gy/pulse with a pulse repetition rate not to exceed 12.5 Hz, or does not exceed an equivalent dose rate of 7.5 kGy/s from continuous sources **(1)**.[2]

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 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 **(2)**. The dichromate 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 above 0°C and should be below 80°C.

NOTE 2—The temperature coefficient of dosimeter response is known only in the range of 5° to 50°C (see 10.1.8). Use outside this range is not recommended.

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.* Specific precautionary statements are given in Note 6.

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 456 Terminology Relating to Quality and Statistics[5]

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

E 1261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing[4]

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

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

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[2] The boldface numbers in parentheses refer to a 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 03.06.

E 1707 Guide for Estimating Uncertainties in Dosimetry for Radiation 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 60 MeV

ICRU Report 33 Radiation Quantities and Units

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

3. Terminology

3.1 *Definitions:*

3.1.1 *absorbed dose (D), n*—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 gray is equivalent to the absorption of 1 joule per kilogram 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 Report 33).

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

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.

3.1.2 *calibration facility*, *n*—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 *dosimetry system*, *n*—a system used for determining absorbed dose, consisting of dosimeters, measurement instruments, and their associated reference standards, and procedures for the system's use.

3.1.4 *measurement quality assurance plan*, *n*—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 *net absorbance, (ΔA), n*—change in measured optical absorbance at a selected wavelength determined as the absolute difference between the pre-irradiation absorbance, A_0, and the post-irradiation absorbance, A, as follows:

$$\Delta A = |A - A_0| \qquad (2)$$

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

NOTE 3—For other terms, see Terminology E 170.

4. Significance and Use

4.1 The dichromate system provides a reliable means for measuring absorbed dose in water. It is based on a process of reduction of dichromate ions to chromic ions in acidic aqueous solution by ionizing radiation.

4.2 The dosimeter is a solution containing silver and dichromate ions in perchloric acid in an appropriate container such as a flame-sealed glass ampoule. The solution indicates absorbed dose by a change (decrease) in optical absorbance at a specified wavelength(s) **(3)**. A calibrated spectrophotometer is used to measure the absorbance.

4.3 *Effect of Irradiation Temperature*:

4.3.1 The dosimeter response has a temperature dependence during irradiation that is approximately equal to −0.2 % per degree Celsius between 25 and 50°C. At temperatures below 25°C, the dependence is smaller. The dosimeter response between 5 and 50°C is shown in Table 1, where the response at a given temperature is tabulated relative to the response at 25°C **(4)**.

4.3.2 The data in Table 1 may be fitted with an appropriate formula for convenience of interpolation as follows:

$$R_T = b_0 + b_1 T^{b2} \qquad (3)$$

where:

R_T = dosimeter response at temperature T relative to that at 25°C.

The fitted data is shown in Fig. 1.

4.4 No effect of ambient light (even direct sunlight) has been observed on dichromate solutions in glass ampoules **(5)**.

4.5 For calibration with photons, the dichromate dosimeter shall be irradiated under conditions that approximate electron equilibrium.

4.6 The absorbed dose in other materials irradiated under equivalent conditions may be calculated. Procedures for making such calculations are given in Practices E 666 and E 668 and Guide E 1261.

4.7 The dosimeter response is dependent on the type and energy of the radiation employed. For example, the response in high energy (10 MeV) electron beams is reported to be approximately 3 % lower than the response in cobalt-60 radiation **(2)**. The dosimeter shall be calibrated in a radiation field of the same type and energy as that in which it is to be used.

5. Interferences

5.1 The dichromate dosimetric solution response is sensitive to impurities, particularly organic impurities. Even in trace quantities, impurities can cause a detectable change in the

TABLE 1 Effect of Irradiation Temperature on Dosimeter Response

Temperature, °C	Response	Temperature, °C	Response
5	1.020	30	0.992
10	1.017	35	0.983
15	1.013	40	0.972
20	1.007	45	0.960
25	1.000	50	0.948

[7] Available from the Commission on Radiation Units and Measurements (ICRU), 7910 Woodmont Ave., Bethesda, MD 20814.