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Practice for use of cellulose acetate dosimetry system

Pratique d'utilisation d'un système dosimétrique de mesure à l'acétate de cellulose

Reference number
ISO 15570:1998(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 15570 was prepared by the American Society for Testing and Materials (ASTM) Subcommittee E10.01 (as E 1650-94) 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 15570 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 1650 – 94

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Standard Practice for Use of Cellulose Acetate Dosimetry System[1]

This standard is issued under the fixed designation E 1650; 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 procedures for the use of cellulose acetate dosimetry systems, and the spectrometric, densitometric, or photometric readout equipment for measuring absorbed dose in materials irradiated by photons and electrons in terms of absorbed dose in water.

NOTE 1—Cellulose acetate dosimeter refers to untinted and tinted cellulose triacetate (CTA) or cellulose diacetate (CDA) film dosimeter.

1.2 This practice applies to cellulose acetate film dosimeters that can be used within part or all of the specified ranges as follows:

1.2.1 The absorbed dose range for untinted CTA and CDA is 5×10^3 to 3×10^5 Gy for photons and electrons,

1.2.2 The absorbed dose range for tinted CTA and CDA is 1×10^4 to 1×10^6 Gy for photons and electrons,

1.2.3 The absorbed dose rate for both CTA and CDA is from 0.03 to 3×10^7 Gy/s,

1.2.4 The radiation energy range for photons is from 0.1 to 50 MeV, and

1.2.5 The radiation energy range for electrons is from 0.2 to 50 MeV.

NOTE 2—In cases where low-energy electrons and charged particles cannot completely penetrate the thickness of standard CTA and CDA films, thin films may be used (**1, 2**).[2]

1.2.6 The irradiation temperature range is from −10 to 70°C.

1.3 *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:*

E 170 Terminology Relating to Radiation Measurements and Dosimetry[3]

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers[4]

E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation[3]

E 925 Practice for the Periodic Calibration of Narrow Band-Pass Spectrophotometers[4]

E 958 Practice for Measuring Practical Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers[4]

E 1026 Practice for Using the Fricke Reference Standard Dosimetry System[3]

E 1205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System[3]

E 1261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing[3]

E 1275 Practice for Use of a Radiochromic Film Dosimetry System[3]

E 1276 Practice for Use of a Polymethlmethacrylate Dosimetry System[3]

E 1310 Practice for Use of a Radiochromic Optical Waveguide Dosimetry System[3]

E 1400 Practice for Characterization and Performance of a High-Dose Gamma Radiation Dosimetry Calibration Laboratory[3]

E 1401 Practice for Use of a Dichromate Dosimetry System[3]

E 1538 Practice for Use of the Ethanol-Chlorobenzene Dosimetry System[3]

E 1540 Practice for Use of a Radiochromic Liquid Solution Dosimetry System[3]

E 1607 Practice for Use of the Alanine-EPR Dosimetry System[3]

E 1608 Practice for Dosimetry in an X-Ray (Bremsstrahlung) Irradiation Facility for Radiation Processing[3]

E 1631 Practice for Use of Calorimetric Dosimetry Systems for Electron Beam Dose Measurements and Dosimeter Calibrations[3]

E 1649 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies between 300 keV and 25 MeV

2.2 *International Commission on Radiation Units and Measurement (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 17 Radiation Dosimetry: X-Rays and Gamma Rays at Potentials of 5 to 150 kV

ICRU Report 33 Radiation Quantities and Units

ICRU Report 34 The Dosimetry of Pulsed Radiation

[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 12.02.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

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

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 Measurement

3. Terminology

3.1 *absorbed dose, D*—quotient of $d\bar{\varepsilon}$ by *dm*, where $d\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass *dm* (see Terminology E 170 and ICRU Report 33). The special name for the unit of absorbed dose is the gray (Gy):

$$1 \text{ Gy} = 1 \text{ J} \cdot \text{kg}^{-1}$$

Formerly, the special unit for absorbed dose was the rad:

$$1 \text{ rad} = 10^{-2} \text{ J} \cdot \text{kg}^{-1}$$

3.2 *absorbed dose mapping*—measurement of the absorbed-dose distribution in an irradiation unit through the use of dosimeters placed at specified locations throughout the product volume.

3.3 *analysis wavelength*—wavelength used in a spectrophotometer, densitometer, or photometer for measuring optical absorbance.

3.4 *calibration curve*—graphical or mathematical relationship between dosimeter response and absorbed dose for a given dosimetry system; this term is also referred to as the response function.

3.5 *cellulose acetate dosimeter*—untinted and tinted cellulose triacetate (CTA) or cellulose diacetate (CDA) film dosimeters that undergo change in optical absorbance or optical density under ionizing radiation.

DISCUSSION—This change in absorbance or optical density is related to radiation chemical change in cellulose acetate, plasticizer and tinted dyes, and can be related to absorbed dose in water.

3.6 *dosimeter batch*—a quantity of dosimeters made from a specific mass of dosimetric material with uniform composition, fabricated in a single production run under controlled, consistent conditions, and having a unique identification code.

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

3.8 *electron equilibrium*—a condition that exists in a material under irradiation when the energies, number, and direction of electrons induced by the radiation are constant throughout the volume of interest; thus, within such a volume, the sum of the energies of all electrons entering it is equal to the corresponding sum of all electrons leaving it.

3.9 *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.

3.10 *net absorbance*, ΔA—the difference between the optical absorbance of an unirradiated film dosimeter, A_o, and the optical absorbance of an irradiated film dosimeter, A.

$\Delta A = A - A_o$ (for increasing absorbance)
$\Delta A = A_o - A$ (for decreasing absorbance)

3.11 *net optical density*, ΔOD—another expression for "net absorbance."

DISCUSSION—This expression is more commonly used for film and plastic dosimeters than for liquid dosimeters.

3.12 *specific net absorbance, k*—net absorbance, ΔA, at a selected wavelength divided by the optical path length, t, through the dosimeter (that is, film thickness) as follows:

$$k = \Delta A/t$$

3.13 *stock*—part of a dosimeter batch, held by the user.

3.14 *traceability*—the ability to show that a measurement is consistent with appropriate national or international standards through an unbroken chain of comparisons.

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

4. Significance and Use

4.1 The cellulose acetate (CTA and CDA) dosimetry systems provide a means of measuring absorbed dose in materials (**3-17**). Under the influence of radiation, chemical reactions take place in the cellulose acetate, plasticizer or dyes in the matrix, changing the optical absorption properties (absorption wavelength (band) and density) (**18**). Absorbance or optical density values are measured at the selected wavelength using a spectrophotometer, densitometer, or photometer.

4.2 In the use of a specific dosimetry system, absorbed dose is evaluated by the use of a calibration curve traceable to national or international standards.

4.3 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 3—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 various products, for example radiation effects tests, polymer modifications, and sterilization of medical devices.

4.5 The available dynamic ranges indicated in 1.2.1 and 1.2.2 are achieved by using a variety of plasticizer and dye concentrations in the CTA and CDA systems.

4.6 The difference in dose response due to changes in the parameters of the irradiation conditions, such as dose rate, temperature, humidity, and atmosphere should be considered when these are different from the parameters of the calibration.

NOTE 4—The dose response of the CTA dosimeter increases linearly with temperature (−10 to 40°C) and relative humidity (20 to 80 %) when irradiated at lower dose-rates (<10 kGy/h) typical of gamma-irradiators. The effects are found to be less severe at the higher dose-rates for electron irradiators (>100 kGy/h). Moreover, as mentioned in Ref **16**, these effects are known to vary from batch to batch. All these effects need to be considered before CTA dosimeters can be used routinely for processing (**6, 9, 11, 12, 16**, and **17**).

5. Apparatus

5.1 The following shall be used to evaluate absorbed dose with cellulose acetate dosimetry systems:

5.1.1 A batch or portion of a batch of cellulose acetate film.

5.1.2 A double-beam UV/visible spectrophotometer or an equivalent instrument having documentation covering: (*1*) the analytical wavelength at which absorbance or optical density is measured (see 8.2); (*2*) the accuracy of wavelength selection, absorbance or optical density reading (see Figs. 1 through 4 for suitable wavelength—for example, 280 nm for CTA and 390 nm for dyed CDA); and (*3*) the spectral wavelength range (in the case of absorption spectral readout as discussed in Ref **16**). In addition, stray light rejection is needed. The spectrophotometer or the equivalent instrument should also be able to read the absorbance up to a value of 2.0 at a suitable wavelength with an uncertainty of no more than ±1 %.

5.1.3 A film holder for spectrophotometry, or equivalent device, should keep the film perpendicular to the analytical beam, or a built-in automatic film feeder at a speed of the order of 0.1 to 1 cm/s with the same specifications of the film holder used for automatic one-dimensional dose profile measurement.

5.1.4 The thickness gage shall be calibrated and traceable to a national standard within a precision of ±1 % of the film thickness at the 95 % confidence level.

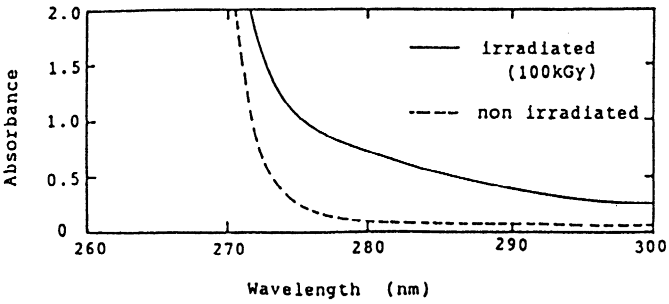
6. Performance Check of Instrumentation

6.1 Check and document the performance of a spectrophotometer or an equivalent instrument, for example, a densitometer or photometer equipped with a narrow band-pass filter at a suitable wavelength (see Practices E 275, E 925, E 958, and E 1026).

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

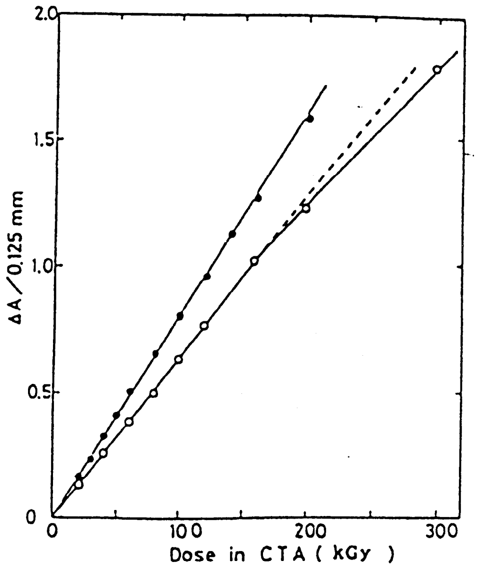
6.1.2 When using a spectrophotometer, estimate and document the precision and bias of the wavelength scale at or near the selected analytical wavelength(s), at intervals not to exceed one month during the period of use, or whenever there are indications of poor performance.

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



NOTE—The suggested wavelength of 280 nm is chosen due to low absorbance before irradiation (A_o), and linear absorbance (A) increase with dose. (Original drawing by the author of Refs **1, 2, and 19**)

FIG. 1 Absorption Spectra Before and After Irradiation of Untinted Cellulose Triacetate (CTA) Film with a 2 MeV Electron Beam



NOTE 1—O: electron beam (dose rate: 10^7 Gy/h, temperature: 15°C, relative humidity: 60 %). ●: gamma-rays (dose rate: 10^4 Gy/h, temperature 25°C, relative humidity: 50 to 60 %)

NOTE 2—The ΔA values were measured 2 h after irradiation (**19**).

FIG. 2 The Relation Between the Increment of Absorbance ΔA/Nominal Thickness (0.125 mm) at 280 nm and Dose in Untinted CTA by Electron and Gamma-Radiation

7. Preparation of Dosimeters

7.1 Cellulose acetate dosimeters can be prepared by pouring a prescribed recipe solution (for example, see Ref **5**) consisting of cellulose diacetate or triacetate, plasticizer, dye, and solvent onto an optical flat plate and evaporating the solvent slowly and gently. The thickness of the film can be controlled by the concentration of solutes or by the amount of solution poured on to a given area of the horizontal plate.

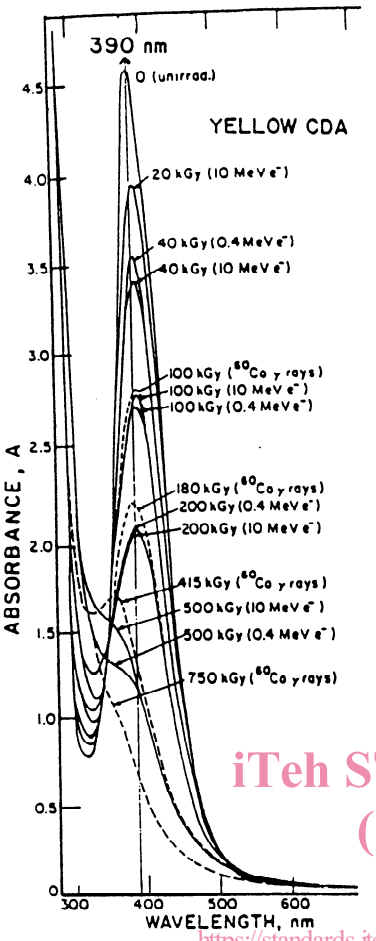
7.1.1 For both untinted and tinted CTA dosimeter films, the recommended recipe is 85 weight % of cellulose triacetate and balance of triphenyl phosphate (TPP) as a sole plasticizer, plus compatible kinds and amounts of solvents, for example, methylenechloride-methanol mixture (**18**).

7.2 In-house preparation of cellulose acetate dosimeters has an advantage that the film thickness can be adjusted according to the intended application, the measurable dose range and the range of the electron beam. The disadvantage lies in the difficulty in making a large size film of constant thickness. Such film may be used for small size dosimeters but, unless the thickness is uniform, may not be used as long strips or large size films for continuous dose mapping purposes.

7.3 Some CTA and CDA films are commercially available, and are described in the nonmandatory appendix of this practice.

8. Calibration of Dosimeters

8.1 *Irradiation:*



NOTE—The suggested wavelength for spectrophotometric analysis for dosimetry is indicated by the vertical arrow. If the spectrophotometer or densitometer is not able to measure very high absorbance ($A_{390\,nm}$ = 4.55), measurement may be made at a higher wavelength on a shoulder of the absorption spectrum (for example, at 410 nm) or using a broad band-pass filter[6] with a densitometer **(16)**.

FIG. 3 Absorption Spectra Before and After Irradiation to High Doses (Using ^{60}Co γ Rays, 0.4- and 10-MeV Electron Beams) of Yellow Cellulose Diacetate (CDA) Film

8.1.1 Randomly select five dosimeters from the batch or stock and do not irradiate them. Use them for determining A_o (see 8.3.1).

8.1.2 Select a set of at least four dosimeters for each absorbed dose value.

8.1.3 Irradiate these sets of dosimeters to at least five known dose values per decade covering the range of utilization, or at least four sets if the range of use is less than one decade.

NOTE 5—If the dose range exceeds a decade, the number of values of dose, N, is calculated by the following equation:

$$N = \text{Nearest integer } [5 \times \log_{10} (D_{max}/D_{min})]$$

For example, if the maximum dose range (D_{max}) is 200 kGy, and the minimum dose range (D_{min}) is 10 kGy,

$$N = \text{Nearest integer } [5 \times \log(200/10)]$$
$$= \text{Nearest integer } [(5 \times 1.301)]$$
$$= \text{Nearest integer } [6.505]$$
$$= 7$$

8.1.4 For calibrating the batch or stock of dosimeters, use an irradiation facility that has a dose rate traceable to appropriate national or international standards and that meets the requirements specified in Practice E 1400. Use a reference or transfer dosimetry system to establish the 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 or in another material appropriate for the specific application (for example, see Practices E 1026 and E 1205).

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

8.1.7 When using photon radiation for calibration, surround the dosimeters with a sufficient amount of water-equivalent material to ensure approximate electron equilibrium condition.

NOTE 6—For example, for a ^{60}Co gamma-ray source, this could be accomplished by surrounding the dosimeter with 3 to 5 mm of polymeric material, (for example, polystyrene or PMMA) in all directions.

8.1.8 When using an electron beam for the calibration, locate the dosimeter in a well characterized position within the radiation field **(17, 20)**.

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 the occupied volume should be within ±1 %.

8.1.10 Control (or monitor) the temperature and humidity of the dosimeters during irradiation. Take into account any temperature and humidity variation that can affect dosimeter response (that is, specific net absorbance). For the dosimeter systems in Table X1.1 the temperature dependence of dosimeter response during gamma-irradiation is about +0.5 % per °C.

NOTE 7—Untinted CTA (FTR-125)[7] does not show appreciable temperature dependence when used at dose rate of 10^6 Gy/h and higher **(21)**. Extremes in relative humidity affect their sensitivity. Therefore, avoid very low (<20 %) and very high humidity conditions (>80 %). For high dose-rate dosimetry (for example, electron beams), the effect of humidity differences on dosimeter response is less severe than at low dose rates (for example, gamma radiation) **(6, 9)**. For high doses exceeding 200 kGy, CTA film becomes brittle and must be handled with care.

8.1.11 Calibrate each batch or stock of dosimeters prior to routine use, and at least once per year.

8.2 *Measurement:*

8.2.1 Depending on the cellulose acetate dosimeter used (see Table X1.1), set the spectrophotometer at the appropriate wavelength at a band width of no more than 1 nm, or use photometer or densitometer equipped with an appropriate band-pass filter or hollow cathode lamp or light-emitting diode (LED) of appropriate wavelength.

8.2.2 Set the balance of the spectrophotometer, densitometer, or photometer to zero absorbance, without a film dosimeter (with only air) in the analytical light beam.

8.2.3 Insert the non-irradiated film dosimeter in the

[6] Corning S5-58, available from Corning, Inc., Technical Products Division, Advanced Materials Dept., Main Plant 21-3, Corning, NY 14831, has been found satisfactory.

[7] See the appendix for the availability address.

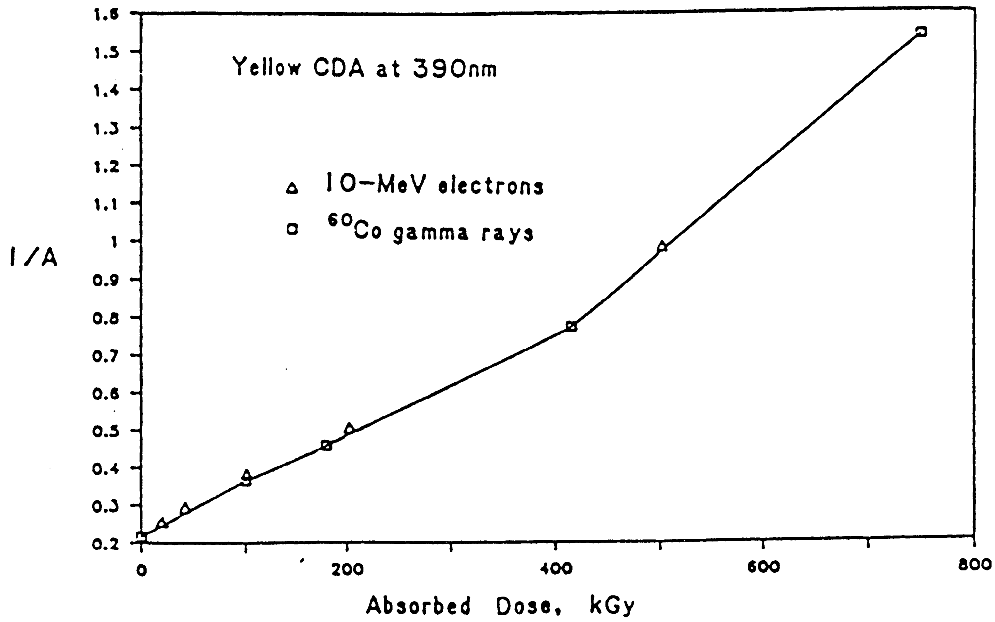


FIG. 4 Increase in the Reciprocal of Absorbance (I/A), at 390 nm Wavelength, as a Function of Absorbed Dose (in Water), when Yellow CDA is Irradiated with Electrons and Gamma Rays (16)

holder and insert it in the analytical light beam of the spectrophotometer, densitometer, or photometer. Measure the absorbance with only air in the reference light beam. Record this value (A_o). With use of the scanning spectrophotometer, densitometer, or photometer, read the average value of absorbance with air as the reference. Record these values (A_o).

8.2.4 Insert the irradiated dosimeter film in the analytical light beam of the spectrophotometer, densitometer, or photometer and measure the absorbance (A). Using a scanning spectrophotometer, densitometer, or photometer, record the value of absorbance along the dosimeter strip with air as the reference.

NOTE 8—For untinted CTA film dosimeters (FTR-125), the absorbance first decreases and then increases with storage time after irradiation. The reading will become stable about 2 h after irradiation. Therefore, it is recommended that the absorbance of CTA film dosimeters be measured at a constant time period (approximately 2 h) after the irradiation.

8.2.5 Measure the thickness, t, of the film dosimeter. Calculate the average absorbance per unit thickness, A_o/t (specific background absorbance). Calculate the average absorbance per unit thickness (specific absorbance) at each dose value, A/t. Using a scanning spectrophotometer, densitometer, or photometer, calculate the value of absorbance per unit thickness A/t along the dosimeter strip.

NOTE 9—With film dosimeters, specific absorbance per centimeter is not always calculated, rather $(A - A_o)$/(nominal thickness) may be used to calculate the dose if a sensitivity factor is supplied for the nominal thickness.

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

NOTE 10—In the case of uniform dosimeters (reproducible readings of A_o), the net absorbance change can be obtained by setting the double-beam spectrophotometer absorbance balance control to "zero" with the presence of a non-irradiated dosimeter in the reference optical beam.

8.3 *Analysis:*

8.3.1 Calculate mean absorbance, A_o, of the unirradiated dosimeter (see 8.2.3). Calculate the net absorbance, ΔA for each irradiated dosimeter as follows:

$\Delta A = A - \bar{A}_o$ (for increasing absorbance with dose) and $\Delta A = \bar{A}_o - A$ (for decreasing absorbance with dose)

NOTE 11—Better precision is achieved when individual $\bar{A}_o$ values (pre-irradiation readings) are taken.

8.3.2 Prepare a calibration curve by plotting specific net absorbance, $\Delta A/t$, versus absorbed dose. Examples of calibration curves are shown in Figs. 2 and 4. Absorption spectra are shown in Figs. 1 and 3.

8.3.3 Fit the data with an appropriate analytical function that provides an acceptable fit to the data. Linear regression best fits the data for untinted CTA and some tinted CDA dosimeters in a relatively narrow absorbed dose range (see Figs. 2 and 4), and second or third order polynomial regression best fits the data for some tinted CDA dosimeters.

8.3.4 Estimate the precision (random uncertainty) of the individual dosimeter readings of the A_o values and the A values at each dose from replicate measurements. The precision, expressed as two standard-deviations should not exceed ±0.03 absorbance units at the 95 % confidence level. Suspected data outliers should be tested and eliminated using statistical procedures such those found in Practices E 177 and E 178.

9. Condition for Practical Use

9.1 *Dosimeter Holder:*

9.1.1 Use a special holder to mount the cellulose acetate film dosimeter pieces in the spectrophotometer, densitometer, or photometer for absorbance measurement.

9.1.2 Alternatively, fit a long film dosimeter tape of