

Guide for estimating uncertainties in dosimetry for radiation processing

ICS 17.240

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National foreword

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Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ISO title page, pages ii to vi, pages 1 to 28, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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INTERNATIONAL STANDARD

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Guide for estimating uncertainties in dosimetry for radiation processing

Guide pour l'estimation des incertitudes en dosimétrie pour le traitement par irradiation



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 15572 was prepared by the American Society for Testing and Materials (ASTM) Subcommittee E10.01 (as E 1707-95) 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 15572 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	<i>Practice for dosimetry in gamma irradiation facilities for food processing</i>
15555	E 1205-93	<i>Practice for use of a ceric-cerous sulfate dosimetry system</i>
15556	E 1261-94	<i>Guide for selection and calibration of dosimetry systems for radiation processing</i>
15557	E 1275-93	<i>Practice for use of a radiochromic film dosimetry system</i>
15558	E 1276-96	<i>Practice for use of a polymethylmethacrylate dosimetry system</i>
15559	E 1310-94	<i>Practice for use of a radiochromic optical waveguide dosimetry system</i>
15560	E 1400-95a	<i>Practice for characterization and performance of a high-dose radiation dosimetry calibration laboratory</i>
15561	E 1401-96	<i>Practice for use of a dichromate dosimetry system</i>
15562	E 1431-91	<i>Practice for dosimetry in electron and bremsstrahlung irradiation facilities for food processing</i>
15563	E 1538-93	<i>Practice for use of the ethanol-chlorobenzene dosimetry system</i>
15564	E 1539-93	<i>Guide for use of radiation-sensitive indicators</i>
15565	E 1540-93	<i>Practice for use of a radiochromic liquid dosimetry system</i>
15566	E 1607-94	<i>Practice for use of the alanine-EPR dosimetry system</i>

ISO Designation	ASTM Designation	Title
15567	E 1608-94	<i>Practice for dosimetry in an X-ray (bremsstrahlung) facility for radiation processing</i>
15568	E 1631-96	<i>Practice for use of calorimetric dosimetry systems for electron beam dose measurements and dosimeter calibrations</i>
15569	E 1649-94	<i>Practice for dosimetry in an electron-beam facility for radiation processing at energies between 300 keV and 25 MeV</i>
15570	E 1650-94	<i>Practice for use of cellulose acetate dosimetry system</i>
15571	E 1702-95	<i>Practice for dosimetry in a gamma irradiation facility for radiation processing</i>
15572	E 1707-95	<i>Guide for estimating uncertainties in dosimetry for radiation processing</i>
15573	E 1818-96	<i>Practice for dosimetry in an electron-beam facility for radiation processing at energies between 80 keV and 300 keV</i>

1 Scope

1.1 This guide defines possible sources of error in dosimetry performed in gamma, x-ray (bremsstrahlung) and electron irradiation facilities and offers procedures for estimating the resulting magnitude of the uncertainties in the measurement results. Basic concepts of measurement, estimate of the measured value of a quantity, “true” value, error and uncertainty are defined and discussed.

Components of uncertainty are discussed and methods are given for evaluating and estimating their values. How these contribute to the standard uncertainty in the reported values of absorbed dose are considered and methods are given for calculating the combined standard uncertainty and an estimate of overall (expanded) uncertainty. The methodology for evaluating components of uncertainty follows ISO procedures (see **2.3**). The traditional concepts of precision and bias are not used. Examples are given in five appendixes.

1.2 This guide assumes a working knowledge of statistics. Several statistical texts are included in the references (**1, 2, 3, 4**).¹⁾

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*²⁾.

E 177, *Practice for Use of the Terms Precision and Accuracy as Applied to Measurement of a Property of a Material*²⁾.

E 178, *Practice for Dealing With Outlying Observations*²⁾.

E 456, *Terminology Relating to Quality and Statistics*³⁾.

E 666, *Practice for Calculating Absorbed Dose from Gamma or X Radiation*²⁾.

E 876, *Practice for Use of Statistics In the Evaluation of Spectrometric Data*⁴⁾.

E 1026, *Practice for Using the Fricke Reference Standard Dosimetry System*²⁾.

E 1204, *Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing*²⁾.

E 1205, *Practice for Use of a Ceric-Cerous Sulfate Dosimetry System*²⁾.

E 1249, *Practice for Minimizing Dosimetry Errors in Radiation Hardness Testing of Silicon Electronic Devices Using Co-60 Sources*²⁾.

E 1261, *Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing*²⁾.

E 1275, *Practice for Use of a Radiochromic Film Dosimetry System*²⁾.

E 1276, *Practice for Use of a Polymethylmethacrylate Dosimetry System*²⁾.

E 1310, *Practice for the Use of a Radiochromic Optical Waveguide Dosimetry System*²⁾.

E 1401, *Practice for Use of a Dichromate Dosimetry System*²⁾.

E 1431, *Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing*²⁾.

E 1607, *Practice for Use of the Alanine-EPR Dosimetry System*²⁾.

2.2 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 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*.

ICRU Report 37, *Stopping Powers for Electrons and Positrons*.

2.3

¹⁾ The boldface numbers in parentheses refer to a list of references at the end of this guide.

²⁾ *Annual Book of ASTM Standards*, Vol 12.02.

³⁾ *Annual Book of ASTM Standards*, Vol 14.02.

⁴⁾ *Annual Book of ASTM Standards*, Vol 03.06.

⁵⁾ Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800 Bethesda, MD 20814.

3 Terminology

3.1 Definitions

3.1.1

absorbed dose, D

quantity of radiation energy imparted per unit mass of a specified material. The unit of absorbed dose is the gray (Gy) where 1 gray is equivalent to the absorption of 1 joule per kilogram (= 100 rad). The mathematical relationship is the quotient of $d\bar{\epsilon}$ by dm , where $d\bar{\epsilon}$ is the mean energy imparted by ionizing radiation to matter of mass dm (see ICRU 33)

$$D = d\bar{\epsilon}/dm$$

3.1.2

accuracy of measurement

closeness of the agreement between the result of a measurement and the true value of the measurand

3.1.3

calibration curve

graphical representation of the relationship between dosimeter response and absorbed dose for a given dosimetry system. For a mathematical representation, see **response function**

3.1.4

coefficient of variation

sample standard deviation expressed as a percentage of sample mean value (see **3.37** and **3.38**)

$$(CV) = S_{n-1}/\bar{x} \times 100 \%$$

3.1.5

combined standard uncertainty

standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities

3.1.6

confidence interval

an interval estimate that contains the mean value of a parameter with a given probability

3.1.7

confidence level

the probability that a confidence interval estimate contains the value of a parameter

3.1.8

corrected result

result of a measurement after correction for the best estimate of systematic error

3.1.9

correction

value that, added algebraically to the uncorrected result of a measurement, compensates for systematic error

DISCUSSION — The correction is equal to the negative of the systematic error. Some systematic errors may be estimated and compensated by applying appropriate corrections. However, since the systematic error cannot be known perfectly, the compensation cannot be complete.

3.1.10

correction factor

numerical factor by which the uncorrected result of a measurement is multiplied to compensate for a systematic error

DISCUSSION — Since the systematic error cannot be known perfectly, the compensation cannot be complete.

3.1.11

coverage factor

numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an overall uncertainty

DISCUSSION — A coverage factor, k , is typically in the range of 2 to 3 (see **8.3**).

3.1.12

dosimeter batch

quantity of dosimeters made from a specific mass of material with uniform composition, fabricated in a single production run under controlled, consistent conditions and having a unique identification code

3.1.13

dosimetry system

a system used for determining absorbed dose, consisting of dosimeters, measurement instruments and their associated reference standards, and procedures for the system's use

3.1.14

error (of measurement)

result of a measurement minus a true value of the measurand

DISCUSSION — Since a true value cannot be determined, in practice a conventional true value is used. The quantity is sometimes called "absolute error of measurement" when it is necessary to distinguish it from relative error. If the result of a measurement depends on the values of quantities other than the measurand, the errors of the measured values of these quantities contribute to the error of the result of the measurement.

3.1.15

expected value

sum of possible values of a variable weighted by the probability of the value occurring. It is found from the expression:

$$E(v) = \sum_i P_i V_i$$

where:

$$V_i = i^{\text{th}} \text{ value, and}$$