INTERNATIONAL STANDARD

ISO 12794

First edition
2000-02-15

Nuclear energy — Radiation protection — Individual thermoluminescence dosemeters for extremities and eyes

Énergie nucléaire — Radioprotection — Dosimètres individuels thermoluminescents pour yeux et extrémités

Reference number
ISO 12794:2000(E)

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. The ISO Central Secretariat accepts no 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. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 734 10 79
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 12794 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

Annexes A, B, C and E form integral parts of this International Standard. Annex D is for information only.

Introduction

This International Standard covers dosemeters for the eyes and extremities.

This International Standard should be used in conjunction with IEC 1066:1991, which provides performance criteria and tests for thermoluminescence dosimetry systems comprising dosemeters, readers, ancillary equipment and procedures for converting light output into dose, for the assessment of personal or environmental doses, excluding extremities. It also includes some performance criteria and tests for thermoluminescent detectors and thermoluminescence dosemeters where these criteria are dependent on the characteristics of the detectors or dosemeters, rather than on the reader or ancillary equipment.

This document was prepared and discussed by Working Group WG 7 of ISO/TC85/SC2 following meetings in Paris in August 1988, Moscow in May 1990, Rome in November 1991, Paris in September 1992 and London in October 1993. It was not possible to hold a WG meeting in Orlando in October 1994. The draft was agreed at the Paris meeting by the working group and circulated by the Secretariat as a CD. A further meeting of the WG was held in London in October but the results of the voting were not available until later in October 1995. A final draft, dated February 1996, incorporating comments included with the results of the voting on ISO/CD (WI 7-2.07.1), circulated as ISO/TC85/SC2 N 475 in October 1993, was agreed by WG 7 in Albuquerque in February 1996. The comments following circulation as a DIS were considered by the WG in July 1997 and this International Standard incorporates those that were agreed upon.

Nuclear energy — Radiation protection — Individual thermoluminescence dosemeters for extremities and eyes

1 Scope

This International Standard provides performance criteria and tests for determining the performance of thermoluminescence dosemeters intended to be used for the measurement of radiation doses to the eyes and extremities (fingers, and limbs defined as hands, feet, forearms including the elbow, and leg including the patella), for photons from 15 keV to 3 MeV and beta radiation from 0,5 MeV to 3 MeV. It is conditional upon the use of an appropriate reader, procedures and ancillary equipment. It does not cover information access and data processing.

This International Standard provides performance criteria and tests for dosemeters intended to measure dose equivalent at depths of 7 $mg \cdot cm^{-2}$ in tissue for fingers and limbs and 300 $mg \cdot cm^{-2}$ in tissue for the eyes, including provision for the use of dosemeters only intended to be used once. Appropriate phantoms and dose conversion coefficients are recommended but others are not precluded.

In all cases, performance is assessed under laboratory conditions which may not adequately simulate conditions actually experienced in personal dosimetry. For example, it may be necessary to sterilize dosemeters for medical applications. Therefore, caution is necessary in applying the results of these performance tests in real situations.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 31-0, *Quantities and units — Part 0: General principles*.

ISO 4037-3:1999, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*.

ISO 6980, *Reference beta radiations for calibrating dosimeters and dose-rate meters and for determining their response as a function of beta-radiation energy*.

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
thermoluminescence
radiothermoluminescence
TL
property exhibited by certain substances, namely the emission of light, which is induced by irradiation when the substance is heated following exposure to ionizing radiation or UV

NOTE Strictly speaking, the property should be referred to as radiothermoluminescence but the abbreviated form thermoluminescence is usually adequate.

3.2
thermoluminescent material
TL material
substance exhibiting the property of thermoluminescence

3.3
thermoluminescent detector
TL detector
detector
specified quantity of TL material, or such material incorporated with other non-luminescent material into a matrix, defined by mass, shape or size or the mass of material incorporated in the matrix

3.4
thermoluminescence dosemeter
TL dosemeter
dosemeter
passive device consisting of one or more TL detectors, which may be mounted in a holder (appropriate for the application), intended to be worn on a person's body or placed in an environment for the purpose of assessing the appropriate dose equivalent at or near the position where it is placed

3.5
thermoluminescence dosemeter reader
TL dosemeter reader
reader
instrument used to measure the light emitted from the detectors in thermoluminescence dosemeters; consisting essentially of a heating device, a light measuring device and the associated electronics

3.6
extremity dosemeter
dosemeter intended to be worn on the finger or limb [hands, feet, forearms (including the elbow), and lower leg (including the patella)]

3.7
eye dosemeter
dosemeter intended to be worn near the eyes

3.8
reusable dosemeter
dosemeter intended to be reused, as opposed to one which is discarded after one use

NOTE When used in medical applications, appropriate sterilization may be necessary.

3.9
batch
collection of detectors or dosemeters made to a specific design or specification and intended to have the same performance characteristics consistent with the appropriate requirements of this International Standard

3.10
annealing
controlled thermal treatment of a TL detector or dosemeter during or after readout

3.11
prepare
reprepare
normal treatment of annealing, cleaning, etc. which the dosemeters or detectors are intended to be subjected to in routine use

3.12
readout
process of measuring the light emitted when a TL detector or dosemeter is heated in a reader

3.13
readout value
m
value indicated by a TL reader after readout of a detector or dosemeter expressed in units appropriate to the output of the reader

3.14
absorbed dose
D
quotient of $\mathrm{d}\bar{\varepsilon}$ by $\mathrm{d}m$, where $\mathrm{d}\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass $\mathrm{d}m$.

NOTE 1 The special name for the unit of absorbed dose is gray (Gy) (1 Gy = 1 J·kg^{-1}). In this International Standard, absorbed doses are specified in grays.

NOTE 2 Where no ambiguity could be involved, the term "absorbed dose" is abbreviated to "dose".

3.15
kerma
K
quotient of $\mathrm{d}\bar{\varepsilon}_{\mathrm{tr}}$ by $\mathrm{d}m$, where $\mathrm{d}\bar{\varepsilon}_{\mathrm{tr}}$ is the sum of the initial kinetic energies of all the charged ionising particles liberated by uncharged ionising particles in a matter of mass $\mathrm{d}m$:

$$K = \frac{\mathrm{d}\bar{\varepsilon}_{\mathrm{tr}}}{\mathrm{d}m} \qquad (1)$$

3.16
dose equivalent
H
product of D *and* Q at the point of interest in tissue where D is the absorbed dose and Q is the quality factor:

$$H = DQ \qquad (2)$$

NOTE The SI unit for both D and H is joule per kilogram. The special name for the unit of dose equivalent is the sievert (Sv): (1 Sv = 1 J·kg^{-1}).

3.17
personal dose equivalent
$H_{\mathrm{p}}(d)$
dose equivalent in soft tissue below a specified point at an appropriate depth, d

NOTE The SI unit for $H_{\mathrm{p}}(d)$ is joule per kilogram. The special name is sievert (Sv) (1 Sv = 1 J·kg^{-1}).

3.18
evaluated value
E
value of the quantity of interest, e.g. dose equivalent (H), air kerma (K_a), free-air absorbed dose ($D_{a)}$, obtained by applying the appropriate evaluation coefficient (F_e) to the readout value or values (m)

3.19
conventional true value
C
best estimate of the quantity of interest at the point of measurement, e.g. dose equivalent (H), air kerma (K_a), free air absorbed dose (D_a)

NOTE This is a widely used standardized term. The grammatically correct synonymous term is Conventionally True Value.

3.20
evaluation coefficient
F_e
factor or collection of factors, used to convert the readout value or values, (m), to the evaluated value of interest (E)

NOTE See annex D.

3.21
residue
readout signal obtained on second readout following normal readout and annealing procedures

3.22
conversion coefficient
F_e
factor used to convert from air kerma or free-air absorbed dose to the corresponding dose equivalent

NOTE See annex E.

3.23
response
R
quotient of the evaluated value and the conventional true value

3.24
self-irradiation
irradiation of the detector due to radioactive impurities contained in the dosemeter holder or detector itself

3.25
phantom
specified object used to simulate the human body or parts thereof in terms of its scattering and absorption of gamma and beta radiation

3.26
zero point
evaluated value of an unirradiated prepared dosemeter or detector

3.27
reader background
evaluated value corresponding to the readout value obtained when the reader is operated without a dosemeter or detector

3.28
detection threshold
minimum evaluated value for which the readout value of a dosemeter or detector is significantly different (at the 95 % confidence level) from the readout value of an unirradiated dosemeter or detector

3.29
coefficient of variation
ratio of the standard deviation s, to the arithmetic mean $\bar{x}$ of a set of n measurements x_i; is gven by the following formula:

$$V = \frac{s}{\bar{x}} = \frac{1}{\bar{x}}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \qquad (3)$$

NOTE The coefficient of variation is generally expressed as a percentage.

3.30
quality control test
QT
test performed on a number of TL dosemeter systems, dosemeters, detectors or readers of a given batch or production designed to assure quality control

3.31
type test
TT
test performed on a small number of TL dosemeter systems, dosemeters, detectors or readers of a given type to determine performance characteristics of that type

4 Units

This International Standard uses SI units. However, the following units of practical importance for time are used where necessary: days (d), hours (h). The symbols of the units for time are provided by International Standard ISO 31-0.

5 General test conditions

5.1 Test conditions

All tests shall be performed under standard test conditions (see annex A), except where otherwise stated. Dosemeters shall be subjected to the annealing, cleaning and handling procedures which are recommended by the manufacturer.

5.2 Reference radiations

The radiation sources specified in ISO 4037-3 and ISO 6980 shall be used in the manner specified in these International Standards. Photon reference radiations used for spectral response checks shall be chosen from the first column of table 1 in 4 of ISO 4037-3:1999. Sources for beta spectral response shall be ^{90}Sr (in equilibrium with ^{90}Y), ^{106}Ru, and ^{204}Tl. Calibration of radiation sources shall be traceable to the appropriate primary or secondary standards.

6 Classification

Dosemeters shall be classified in accordance with body part and the depth of intended measurement, and method of intended use viz:

F(7)D Finger, depth 7 mg·cm^{-2}, disposable;

F(7)R Finger, depth 7 mg·cm^{-2}, re-usable;

L(7)D	Limb, depth 7 mg·cm^{-2}, disposable;
L(7)R	Limb, depth 7 mg·cm^{-2}, re-usable;
E(300)D	Eye, depth 300 mg·cm^{-2}, disposable;
E(300)R	Eye, depth 300 mg·cm^{-2}, re-usable.

7 Performance requirements

The performance criteria are listed in Table 1. All dose values listed in the criteria are in terms of dose equivalent to tissue at the intended depth of measurement*. The conventional true value of the dose equivalent, C, for any specific tests may be obtained by using the conversion coefficients specified in annex E, for each type of intended measurement (finger, limb or eyes). In this International Standard, conversion coefficients are only provided for tissue depths of 7 mg·cm^{-2} and 300 mg·cm^{-2}.

Annex E includes conversion coefficients for selected phantoms for photons and beta radiation. The selected phantoms are a solid 19 mm diameter cylinder of PMMA (ISO PMMA rod) for the finger, a 73 mm diameter water-filled cylinder of PMMA (ISO water pillar) for the limb, both of length 300 mm, and the ICRU sphere or 30 cm × 30 cm × 15 cm water-filled PMMA slab (ISO water slab) for the eyes. The use of other coefficients or phantoms is not precluded and shall be agreed between the manufacturer and the purchaser. The evaluated value of the dose equivalent, (E), shall be determined from the readout value in accordance with annex E. However, in the case of purely comparative tests (i.e. all except energy response and isotropy), the readout values may be used instead of evaluated values.

The performance requirements are identified in Table 1 as type tests (T) or quality control tests (Q). Type tests are intended to demonstrate the basic performance of the type of dosemeter and quality control tests are intended to verify the performance of a specific production or delivery batch of dosemeters.

The number of dosemeters used for each test or repeated tests shall be such that the performance requirements are demonstrated to be met to 95 % confidence. The number, n, of dosemeters (or irradiations) used for any test need not be the same for each test but may be determined using annex B. However, it may be convenient to use, arbitrarily, 5, 10 or 20 dosemeters (or irradiations), in which case the Student's t-value, obtained from annex B, Table B.1, would be 2,78, 2,26 or 2,09 respectively.

Where the response to neutrons is greater than 1 % of the response to photons, in terms of dose equivalent, the manufacturer shall draw the attention of the user to this fact and provide appropriate quantitative information.

Performance requirements are specified in terms of the dose equivalent at appropriate tissue depths, the conventional true value in testing being determined using conversion coefficients for appropriate phantoms. One school of thought suggests that this quantity should be called $H_{\mathrm{p}}(d)$, analogous with measurements on the body. However, neither the International Commission on Radiological Protection (ICRP) nor the International Commission on Radiation Units and Measurements ICRU have specifically addressed the question of a name for the measurement quantity for extremities. The measurement quantity is therefore specified in this International Standard in the way described but is not named.

8 Test methods

Suggested tests to demonstrate compliance with the specified performance requirements are specified in annex C. Alternative tests which equally demonstrate compliance are not precluded.

9 Certification

Manufacturers claiming compliance (or part compliance) with the performance requirements of this International Standard should provide a signed certificate including the following details:

a) names and addresses of the manufacturer and test laboratories;

b) description/specification of the dosemeters under consideration, including dosemeter classification;

c) description of reader, procedures and ancillary equipment used for the tests (Model, No., etc.);

d) statements certifying the results of each test, and dates undertaken (test reports should be available for inspection by the purchaser);

e) statement giving the quantitative response to neutrons, if required;

f) details of conversion coefficients and phantoms agreed between the manufacturer and the purchaser, where those specified in this International Standard are not used.

NOTE In the situation where all tests are not done in the same establishment, the certificate should clearly identify the individual test laboratories for each test.

Table 1 — Performance requirements for extremity and eye dosemeters

No.	Performance characteristic	Class of dosemeter	Performance requirements	Test required [a]
1	Batch homogeneity	R/D	The coefficient of variation of the evaluated value for n dosemeters shall not exceed 15 % for a dose of 10 mSv or less	Q
2	Reproducibility	R	The coefficient of variation of the evaluated value for n dosemeters shall not exceed 10 % for each dosemeter separately for a dose of 10 mSv or less	Q
		D	No requirement	
3	Linearity	R/D	The response shall not vary by more than 10 % over the dose equivalent range 1 mSv to 1 Sv	T
4	Stability of dosemeters under various climatic conditions	R/D	The evaluated values of dosemeters irradiated either at the beginning or at the end of a storage period shall not differ from the conventional true value by more than 5 % for 30 d storage under standard test conditions, or 10 % for 48 h storage at 40 °C and 90 % relative humidity	T
5	Detection threshold	R/D	The detection threshold shall not exceed 1 mSv	T
6	Self- irradiation	R/D	After a storage period of 60 days, the zero point shall not exceed 2mSv	T
7	Residue	R	After irradiation with a conventional true value of 100 mSv, the detection threshold limit shall not be exceeded and the response shall remain within the requirement for linearity at a dose level of 2 mSv	T
8	Effect of light exposure on the dosemeter	R/D	As a result of exposure to 1 000 $W \cdot m^{-2}$ equivalent to bright sunlight (295 nm to 769 nm) for 1 d, the zero point shall not change by more than 1 mSv and, for exposure during one week, the evaluated value shall not differ from the evaluated value of a dosemeter kept in the dark by more than 10 %	T
9	Isotropy (photons)	R/D	When irradiated with photons of (60 $\pm$ 5) keV, the mean value of the response at angles of incidence of 0^o, 20^o, 40^o and 60^o from normal shall not differ from the corresponding response for normal incidence by more than 15 %	T
10	Energy response (photons)	R/D	When irradiated with photons in the energy range 15 keV to 3 MeV, response shall not vary by more than $\pm$ 50 %	T
11	Energy response (beta radiation)	R/D	When irradiated with beta radiation in the energy range (E_{max}) 0,5 MeV to 3 MeV, the response shall not vary by more than $\pm$ 50 %	T

[a] T: Type.
Q: Quality control.

Annex A
(normative)

Reference conditions and standard test conditions

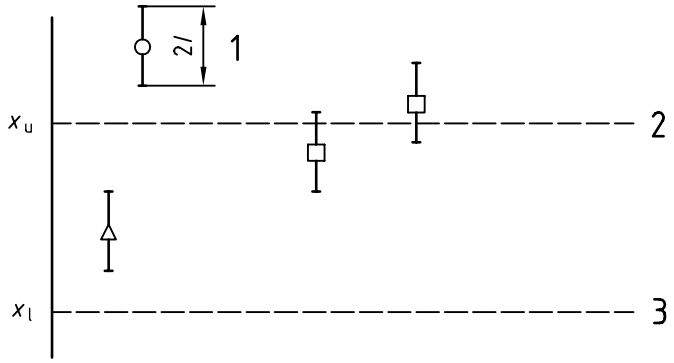
Influence quantity	Reference conditions (unless otherwise stated by the manufacturer)	Standard test conditions (unless otherwise stated by the manufacturer)
Reference photon radiation	To conform to ISO 4037-3	To conform to ISO 4037-3
Reference beta radiation	To conform to ISO 6980	To conform to ISO 6980
Ambient temperature	20 °C	18 °C to 22 °C
Relative humidity	65 %	55 % to 75 %
Gamma radiation background	$\leqslant$ 0,2 μGy·h^{-1}	$\leqslant$ 0.2 μGy·h^{-1}
Contamination by radioactive elements	Negligible	Negligible
Light intensity	50 W·m^{-2}	< 100 W·m^{-2}

Annex B
(normative)

Confidence limits

B.1 General

If the magnitude of the random uncertainty of a measured value is a significant fraction of the permitted tolerances of this measured value, the random uncertainty has to be considered by taking more than one measurement. The number of measurements or the sample size has to be chosen in such a way that the confidence interval obtained for each mean, $\bar{x}$, for a confidence level of 95 % lies either within the limits of variation of the measured value permitted in the test (test passed, points △ in Figure B.1) or outside of these limits (test failed, points ○ in Figure B.1). If one of the permitted limits of variation, x_u or x_l, lies within the confidence interval of the mean (points □ in Figure B.1) the number of measurements or the sample size can be increased to reduce the width 2 I of the confidence interval of the mean $\bar{x}$, in order to reach one of the two cases mentioned above, which are necessary for an unequivocal decision of passing the test or not.



Key

1 Confidence interval of the mean width 2 I

2 Permitted upper limit of variation, x_u

3 Permitted lower limit of variation, x_l

Figure B.1 — Test for confidence interval

The test is passed if the confidence interval of width 2 I around $\bar{x}$ lies between the permitted upper and lower limit of variation, x_u and x_l:

$$x_l + I < \bar{x} < x_u - I \qquad \text{(B.1)}$$

In each test, it is recommended to start with 10 measurements for each dosemeter. If it turns out to be necessary to reduce the width 2 I of the confidence interval of the experimental standard deviation, the number of measurements should be increased (see B.2).

Occasionally, it is more convenient to carry out a test (including, for example, an irradiation) with a certain number of different dosemeters withdrawn at random from the batch instead of repeating a number of measurements with the same dosemeter. There are no objections to such a procedure but the random uncertainties of the test results may be increased.

B.2 Confidence interval for the standard deviation, s

The confidence interval for the standard deviation of the means s is:

$$(s - I_s, s + I_s) \tag{B.2}$$

where I_s is the half-width of the confidence interval of s. If s is calculated from n_s measurements, the upper limit of I_s at a confidence level of 95 % is given by:

$$I_s(n_s) = t_{ns} \cdot s \sqrt{\frac{1}{2(n_s - 1)}} \tag{B.3}$$

where t_{ns} is taken from table B.1 for n_s measurements. By way of example, I_s (10) = 0,53s is obtained for 10 dosemeters.

B.3 Confidence interval for the mean, $\bar{x}$

The confidence interval for the mean $\bar{x}$ is:

$$(\bar{x} - I_i,\ \bar{x} + I_i) \tag{B.4}$$

where I_i, is the half-width of the confidence interval of x relative to the ith set of measurements. When calculating $\bar{x}$ from n_i measurements, the half-width of the confidence interval is given by:

$$I_i = \frac{t_n s_i}{\sqrt{n_i}} \tag{B.5}$$

where s_i is the standard deviation for the ith group of measurements, and t_n is taken from Table B.1 for n_i measurements.

For example, for $n_i = 10$, $I_i = \frac{2{,}26 s_i}{\sqrt{10}} = 0{,}71 s_i$

Table B.1 — Student's t-values for 95 % confidence interval

n_i	t_n	n_i	t_n
2	12,71	15	2,15
3	4,30	20	2,09
4	3,18	25	2,06
5	2,78	30	2,05
6	2,57	40	2,02
7	2,45	60	2,00
8	2,37	120	1,98
9	2,31	∞	1,96
10	2,26		

B.4 Confidence interval for a combined quantity

If the limits of variation are stated for a quantity x, the mean value calculated from k means, $\bar{x}_1$, $\bar{x}_2$, $\bar{x}_3$,... $\bar{x}_k$, is:

$$\bar{x} = f(\bar{x}_1, \bar{x}_2, \bar{x}_3, \ldots \bar{x}_k) \qquad \text{(B.6)}$$

and the half-width of the confidence interval of the ith mean is I_i, the half-width, I, of the confidence interval for $\bar{x}$ is given by :

$$I = \sqrt{\sum_{i=1}^{k} \left(\frac{\delta \bar{x}}{\delta x_i} \right)^2 I_i^2} \qquad \text{(B.7)}$$

EXAMPLE 1 $\bar{x} = \bar{x}_1 \pm \bar{x}_2$ hence $I = \sqrt{(I_1^2 + I_2^2)}$.

in general $\bar{x} = \sum_{i=1}^{n} \bar{x}_i$ hence $I = \sqrt{\sum_{i=1}^{n} I_i^2}$

EXAMPLE 2 $\bar{x} = \frac{\bar{x}_1}{\bar{x}_2}$ hence $I = \frac{\bar{x}_1}{\bar{x}_2} \sqrt{\left(\frac{I_1}{x_1} \right)^2 + \left(\frac{I_2}{x_2} \right)^2}$

EXAMPLE 3 $\bar{x} = \frac{x_1 / x_2}{x_1 + x_2}$ hence $I = \frac{2}{(\bar{x}_1 + \bar{x}_2)^2} \sqrt{(\bar{x}_2 I_1)^2 + (\bar{x}_1 I_2)^2}$

Annex C
(normative)

Performance tests

C.1 Batch homogeneity (Types R and D)

Prepare and irradiate n dosemeters to the same conventionally true value (C) of 10 mSv or less. Determine the evaluated value (E) for each dosemeter and show that the coefficient of variation for the n dosemeters does not exceed 15 %.

C.2 Reproducibility (Type R)

Prepare, irradiate and read out n dosemeters. Repeat this 10 times. The conventional true value shall be exactly the same each time and about 10 mSv or less.

For each of the n dosemeters, determine the mean evaluated value, $\overline{E}_j$, and the standard deviation, s_{Ej}.

Show that for each of the n dosemeters:

$$\frac{100\ (s_{Ej} + I_s)}{\overline{E}_j} \leqslant 10 \qquad \text{(C.1)}$$

Where I_s is given in expression (B.2).

C.3 Linearity (Types R and D)

Prepare, irradiate and read out four groups of dosemeters. Let n_i be the number of dosemeters in the ith group. The conventional true values (C_i) given to each group shall be 0,001 Sv, 0,01 Sv, 0,1 Sv and 1 Sv.

Calculate the mean evaluated value ($\overline{E}_i$) at each irradiation level and its standard deviation $S_{\overline{E}}$.

Show that:

$$0{,}90 \leqslant \frac{\overline{E}_i \pm I_i}{C_i} \leqslant 1{,}10 \qquad \text{(C.2)}$$

Where I_i is obtained from equation (B.5) for n dosemeters. The uncertainties in C_i are considered negligible.

C.4 Stability of dosemeters under various climatic conditions (Types R and D)

Prepare two groups of n dosemeters each. Store both groups for 24 h under standard conditions.

Irradiate group 1 to a known conventional true value (C) of about 10 mSv.

Store both groups of dosemeters in a climatic chamber in which standard test conditions prevail.

After a continuous period of 30 d, remove both groups of dosemeters from the climatic chamber. Irradiate group 2 to the same conventional true value as group 1.

Store both groups for 1 d under standard test conditions. Determine the evaluated values (E) for each dosemeter and calculate the mean of the evaluated values ($\overline{E}$) for each of the two groups and the respective standard deviations, s.

Show that for each group:

$$0{,}95 \leqslant \frac{\overline{E} \pm I_i}{C} \leqslant 1{,}05 \qquad \text{(C.3)}$$

where I_i is calculated according to equation (B.5).

Repeat the test for a storage period of 2 d but in a climatic chamber in which the temperature is 40 °C ± 2 °C and the relative humidity is at least 90 %.

Show that for each group :

$$0{,}90 \leqslant \frac{\overline{E} \pm I_i}{C} \leqslant 1{,}10 \qquad \text{(C.4)}$$

where I_i is calculated according to equation (B.5).

C.5 Detection threshold (Types R and D)

Prepare and read out n dosemeters.

Determine the evaluated value (E) for each (unirradiated) dosemeter and calculate the standard deviation ($s_{\overline{E}}$) for all n dosemeters.

Show that:

$$E + 1 \leqslant 10 \text{ mSv} \qquad \text{(C.5)}$$

C.6 Self irradiation (Types R and D)

Prepare n dosemeters. Store them for 60 d under standard test conditions in a location where the background dose rate is known.

Read out the dosemeters and determine the evaluated value (E). Calculate the mean of the evaluated values ($\overline{E}$) for all n dosemeters and the standard deviation. Determine the conventional true value, C_B (background), due to the background irradiation during storage.

Show that:

$$(\overline{E} + I_i) - C_B \leqslant 2 \text{ mSv} \qquad \text{(C.6)}$$

where I_i is the half-width of the confidence interval, determined as in equation (B.5).

C.7 Residue (Type R)

C.7.1 Effect on detection threshold

Prepare, irradiate and read out the n dosemeters used for the detection-threshold test. The conventional true value (C) shall be about 100 mSv.

Using the same dosemeters, repeat the test for detection threshold.

C.7.2 Effect on response

Prepare, irradiate and read out the same n dosemeters used above. The conventional true value, (C) shall be about 2 mSv.

Determine the evaluated value (E) for each dosemeter and calculate the mean of the evaluated values ($\overline{E}$) and the standard deviation, $s_{E.}$

Show that:

$$0{,}90 \leqslant \frac{\overline{E} \pm I_i}{C} \leqslant 1{,}10 \qquad \text{(C.7)}$$

where I_i is determined according to equation (B.5).

C.8 Effect of exposure to light (Types R and D)

C.8.1 Effect on zero point

Prepare two groups of 20 dosemeters each.

Expose group 1 to 1 000 W·m^{-2} of light for 1 d. Ensure that the temperature of the dosemeters is maintained at less than 40°.

To produce 1 000 W·m^{-2} of light, use apparatus which produces light whose spectrum corresponds to that of bright sunlight (295 nm to 769 nm), (for example with a xenon lamp equipped if necessary with appropriate filters), or use a daylight fluorescent lamp.

NOTE 1 000 W·m^{-2} bright sunlight includes 60 W·m^{-2} of UV.

Store the group 2 dosemeters in the dark in an otherwise identical environment. Ensure that the temperature of group 2 dosemeters is within ± 5 °C of the group 1 dosemeters.

After 1 d, read out all dosemeters.

Determine the evaluated value (E) for each group and calculate the mean of the evaluated values ($\overline{E}$) for each of the two groups and their respective standard deviations.

Show that:

$$\left| \left(\overline{E}_{\text{group 1}} - \overline{E}_{\text{group 2}} \right) \right| + I \leqslant 1{,}0 \text{ mSv} \qquad \text{(C.8)}$$

where I is calculated according to equation (B.7) for the difference of two means.

C.8.2 Effect on response

Prepare and irradiate two groups of 20 dosemeters each. The conventional true value (C) shall be about 10 mSv.

Expose and store groups 1 and 2 respectively as above.

After one week, read out all dosemeters.

Determine the evaluated value (E) for each and calculate the mean of the evaluated values $\left(\overline{E}\right)$ for each of the two groups, and their respective standard deviations.

Show that:

$$0{,}90 \leqslant \frac{\overline{E}_{\text{group 1}}}{\overline{E}_{\text{group 2}}} \pm I \leqslant 1{,}10 \qquad \text{(C.9)}$$

where I is calculated from equation (B.7) for the quotient of two means.

C.9 Isotropy (photons) (Types R and D)

Prepare, irradiate on a phantom and read out four groups of n dosemeters. Let n_i be the number of dosemeters of the ith group. The conventional true value C shall be about 10 mSv using photons of energy (60 ± 5) keV (X-radiation or ^{241}Am) and for the following conditions:

— group 1: normal incidence;

— group 2: 20° off normal;

— group 3: 40° off normal;

— group 4: 60° off normal.

For each group, the angle of incidence for the n irradiations is varied in a positive and negative direction in two planes perpendicular to each other and to the plane of the dosemeter.

Determine the evaluated value (E) for each dosemeter (see Table E.1) and calculate the mean of the evaluated values ($\overline{E}_i$) for each of the four groups and the respective standard deviations.

Show that:

$$0{,}85 \leqslant \frac{\sum \overline{E}_i}{4\overline{E}_1} \pm I \leqslant 1{,}15 \qquad \text{(C.10)}$$

where I is determined according to equation (B.7).

C.10 Energy response (photons) (Types R and D)

Prepare, irradiate on a phantom and read out four groups of n dosemeters each. The conventional true value (C) shall be about 10 mSv using the following reference radiations:

— group 1: 15,8 keV;

— group 2: in the range 30 to 40 keV;

— group 3: in the range 80 to 100 keV;

— group 4: ^{137}Cs or ^{60}Co.

NOTE These are the minimum requirements to fully comply with this International Standard. Additional reference radiations may be used.

Determine the evaluated value (E) for each dosemeter (see Table E.2) and calculate the mean of the evaluated values, $\left(\overline{E}\right)$ for each of the four groups and the respective standard deviations.

For each group show that:

$$0{,}5 \leqslant \frac{\overline{E}_i \pm I_i}{C} \leqslant 1{,}5 \quad (\text{for } i = 1, 2, 3, 4) \qquad \text{(C.11)}$$

where I_i is determined according to equation (B.5).

C.11 Energy response (beta radiation) (Types R and D)

Prepare, irradiate on a phantom and read out two groups of n dosemeters each. The conventional true value (C) shall be about 10 mSv using the following reference radiations:

— group 1: ^{90}Sr/^{90}Y;

— group 2: ^{204}T1.

Determine the evaluated value (E) for each dosemeter (see Table E.3) and calculate the mean of the evaluated values ($\overline{E}$) for each of the two groups.

For each group show that:

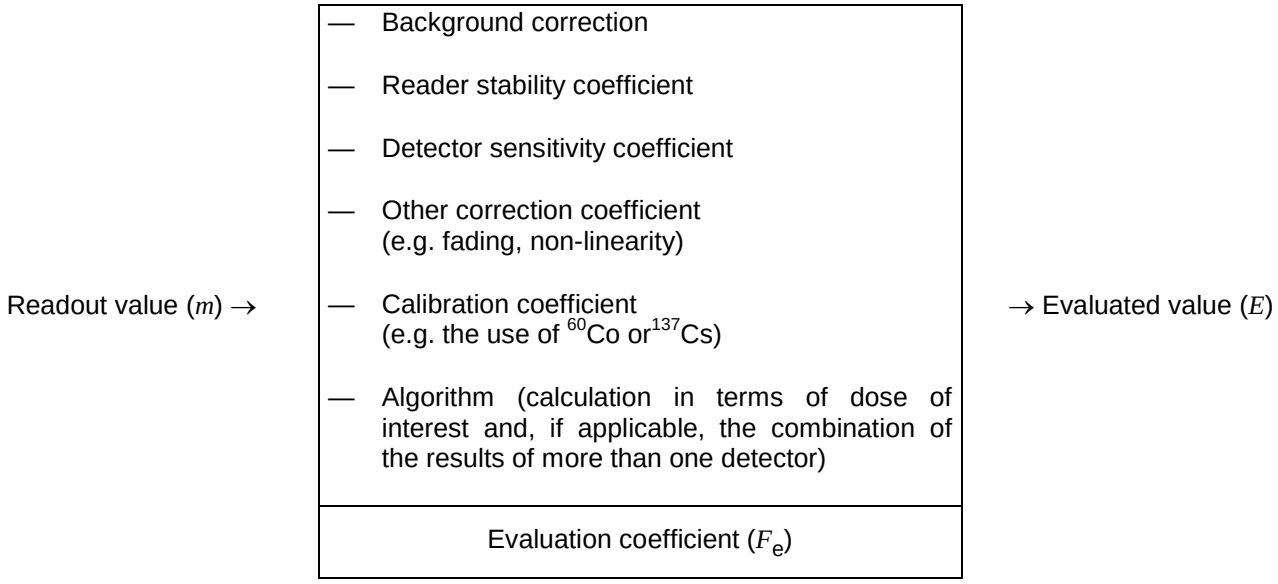
$$0{,}5 \leqslant \frac{\overline{E}_i \pm I_i}{C} \leqslant 1{,}5 \qquad \text{(C.12)}$$

where I_i is determined according to equation (B.5).

Annex D
(informative)

Determination of evaluated value (E) from readout values

To determine the evaluated value of dose that a TL dosemeter is expected to measure, at least one and sometimes more TL detectors are read in the TL reader, leading to one or more readout values. In order to convert the results of these readout values (m) into the final answer, a number of steps have to be made, depending on the TLD system being used and how it is used. The following diagram indicates, as an example, what steps may be involved.



In any particular situation, some of these coefficients may not be necessary and other coefficients may have to be introduced. For this reason, in this International Standard one single coefficient is assumed to replace the entire process, namely the evaluation coefficient (F_e), which converts the readout value (m) into the evaluated value (E).

Annex E
(normative)

Conversion tables

Table E.1 — Conversion coefficients — Air kerma to dose equivalent to tissue for (60 ± 5) keV monoenergetic photons or mean energy ISO narrow-spectrum X-radiation (Sv/Gy)

Depth in tissue	7 mg·cm^{-2}	7 mg·cm^{-2}	300 mg·cm^{-2}
Angle of incidence [a]	**Finger** [b]	**Limb** [b]	**Eye** [c]
0°	1,14	1,39	1,81
20°	1,14	1,39	1,78
40°	1,14	1,38	1,74
60°	1,14	1,33	1,54

[a] Oblique incidence relative to the cylinder axis.

[b] B. Grosswendt, *Radiat. Prot. Dosim.* **59,** (3), pp. 195-203 (1995), Tables 1 and 2.

[c] B. Grosswendt, *Radiat. Prot. Dosim.* **35,** (4), pp. 221-235 (1991), Table 1. (ICRU tissue slab, by interpolation).

Table E.2 — Conversion coefficients — Air kerma to dose equivalent to tissue for normal incidence photons (Sv/Gy)

Depth in tissue	7 mg·cm^{-2}	7 mg·cm^{-2}	300 mg·cm^{-2}
Photon energy	**Finger** [a]	**Limb** [a]	**Eye** [b]
15 keV	0,98	0,98	0,683
30 keV	1,06	1,18	1,223
40 keV	1,09	1,29	1,496
80 keV	1,16	1,38	1,809
100 keV	1,17	1,35	1,743
^{137}Cs	1,12	1,15	1,226
^{60}Co	1,11	1,12	1,182

[a] B. Grosswendt, *Radiat. Prot. Dosim.* **59,** (3), pp. 165-179 (1995), Table 1 (ICRU tissue).

[b] B. Grosswendt, *Radiat. Prot. Dosim.* **35,** (4), pp. 221-235 (1991), Table 1 (ICRU tissue slab).

Table E.3 — Conversion coefficients — Free-air absorbed dose to dose equivalent to tissue for normal incidence betas

Depth in tissue	7 mg·cm^{-2}	7 mg·cm^{-2}	300 mg·cm^{-2}
Beta Energy	**Finger** [a]	**Limb** [a]	**Eye** [b]
$^{90}Sr/^{90}Y$	1,25	1,25	0,6
^{204}Tl	1,22	1,22	n/a

[a] British Committee on Radiation Units (BCRU), *Radiat. Prot. Dosim.* **14**, (4), pp. 337-343, (1986), Table 3, for the ICRU sphere but assumed to be valid for smaller phantoms.

[b] The transmission of ^{240}Tl beta particles through 300 mg·cm^{-2} is zero.

Bibliography

[1] IEC 1066:1991, *Thermoluminescence dosimetry systems for personal and environmental monitoring.*

[2] ICRP[1)] Publication 60:1991, *1990 Recommendations of the International Commission on Radiological Protection*.

[3] ICRU[2)] Report 33:1980, *Radiation quantities and units*.

[4] ICRU Report 39:1985, *Determination of dose equivalent resulting from external radiation sources*.

[5] ICRU Report 43:1988, *Determination of Dose Equivalents from External Radiation Sources — Part 2*.

[6] ICRU Report 47:1992, *Measurement of Dose Equivalents from External Photon and Electron Radiations*.

[7] ICRU Report 51:1993, *Quantities and Units in Radiation Protection Dosimetry*.

1) ICRP is the acronym for International Commission on Radiological Protection.

2) ICRU is the acronym for International Commission on Radiation Units and Measurements.

ICS 13.280

Price based on 20 pages