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Passive neutron dosimetry systems —

Part 1: Performance and test requirements for personal dosimetry

Systèmes dosimétriques passifs pour les neutrons —

Partie 1: Exigences de fonctionnement et d'essai pour la dosimétrie individuelle

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html. This document was prepared by technical committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This second edition cancels and replaces ISO 21909:2015, which has been technically revised.

The main changes compared to the previous edition, based on feedbacks from laboratories applying ISO 21909-1, are as follows:

— link between ISO 21909-1 and ISO 21909-2 improved by the addition of a flow chart explaining the link between the two parts;

— irradiations qualities for the energy test modified:

  — fast energy range enlarged to a range between 10 MeV and 19 MeV;

  — modification of the possible relative contribution of the thermal field in the mixed field composed of ^{252}Cf or ^{241}Am-Be with a thermal one;

— modification in the tests and/or criteria for:

  — the test to potentially eliminate the use of the full neutron and photon package;

  — the test of the coefficient of variation: criteria given by a function;

  — the linearity test: modifications in the equation and associated criteria consequently;

  — the energy and angle dependence of the response test: modification of the performance limits using trumpet curves;

  — alignment of the criteria for the following 3 tests: Stability under various climatic conditions/ effect of light exposure (opacity to light) / effect of storage, all for unexposed dosemeters.

A list of all parts in the ISO 21909 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document gives laboratory-based performance and test requirements for passive dosimetry systems to be used for the determination of personal dose equivalent, $H_p(10)$, in neutron fields with energies ranging from thermal to approximately 20 MeV.

A dosimetry system may consist of the following elements:

a) a passive device, referred to here as a detector, which, after the exposure to radiation, stores information (signal) for use in measuring one or more quantities of the incident radiation field;

b) a dosemeter, made up of one or more detector(s) incorporated together and with some means of identification;

c) a reader which is used to read out the stored signal from the detector, and the associated algorithm, if applicable, aiming to determine the personal dose equivalent.

A treatment to prepare the dosemeter before irradiation and/or before reading is also part of the process and is considered in the document.

This document does not focus on any technique in particular, but intends to be general, including new techniques as they emerge. When distinctions are necessary, they are defined as generically as possible, e.g., disposable/reusable dosemeters and photon-sensitive dosemeters. In conclusion, no performance tests are dedicated to one particular technique, unless it is absolutely necessary. Consequently, this document aims to define performance tests leading to similar results, independently of the techniques used.

The main objective of this document is to achieve correspondence between performance tests and conditions of use at workplaces. Dosimetry systems complying with this document exhibit consistent annual dosimetry results in workplace environments. Reaching such an objective means that this document accounts for the various situations of exposure in terms of dose levels and neutron energy distributions.

Annual exposures of many workers comprise the sum of several low doses close to the minimum recording value. The dosemeter needs therefore to be well characterized, not only for use in relatively high dose situations but also for use in low dose situations, to ensure that the annual dose is determined with an adequate uncertainty. In this document, false positive events when there is not any irradiation, are considered but there is no test of the detection threshold by measuring the background signal of the dosemeter when it is not irradiated. However, all the tests aimed at characterizing the dosimetric performance of the system (coefficient of variation and linearity, energy and angle dependence of the responses) are required at two levels of dose: around 1 mSv and close to the minimum recording value. The criteria applied at these two levels of dose could differ. This choice is made to ensure that dosimetric systems are adapted to the range of doses usually encountered at workplaces.

The main goal of this document is to ensure that a dosemeter is reliable enough to use in most workplaces. Reference neutron radiation characteristics and methodologies for the proper calibration of the dosemeters are reported in ISO 8529 (all parts), ISO 12789-1 and ISO 29661. The dose equivalent distributions of the most common reference radiation sources (e.g. ^{241}Am-Be or ^{252}Cf) as used for calibration are generally higher in energy (where the fluence-to-dose-equivalent conversion coefficients are greater) than the ones encountered in workplaces. The performance of the dosemeters for neutron energies between a few tens and a few hundreds of keV specifically needs to be determined to ensure good response in most of the workplaces. To address this need, some performance tests with mono-energetic neutrons fields at low energies are required in this document.

One well-characterized neutron field (e.g., ^{241}Am-Be or ^{252}Cf) is sufficient to test the stability of dosimetric performances for influencing factors (e.g., fading, ageing, the impact of non-neutron radiation on the neutron signal, harsh climatic conditions, light exposure, physical damage, and sealing).

This document does not present performance tests for characterizing any type of potential degradation (see Scope). However, to ensure the stability of the dosimetry system, it is necessary for the laboratory to evaluate the potential degradation and/or set adapted controls on processing.

For the case that a dosimetry system does not comply with the full range of requirements of this document with regard to the dependence of the response on the energy and direction distributions of the neutron fluence, it is necessary to evaluate the performance for the conditions of the selected workplace. This is addressed in ISO 21909-2 which gives methodologies and criteria to qualify the dosimetry system at the workplace. Even when the dosimetry system fulfils the requirements of this document, it may still be desirable to make a similar study at the workplace.

This document may be extended in the future to another part for the ambient dose equivalent $H^*(10)$ for ambient and environmental dosimetry.

Passive neutron dosimetry systems —

Part 1:
Performance and test requirements for personal dosimetry

1 Scope

This document provides performance and test requirements for determining the acceptability of neutron dosimetry systems to be used for the measurement of personal dose equivalent, $H_p(10)$, for neutrons ranging in energy from thermal to 20 MeV[1)].

This document applies to all passive neutron detectors that can be used within a personal dosemeter in part or in all of the above-mentioned neutron energy range. No distinction between the different techniques available in the marketplace is made in the description of the tests. Only generic distinctions, for instance, as disposable or reusable dosemeters, are considered.

This document describes type tests only. Type tests are made to assess the basic characteristics of the dosimetry systems and are often ensured by recognized national laboratories

This document does not present performance tests for characterizing the degradation induced by the following:

— intrinsic temporal variability of the quality of the dosemeter supplied by the manufacturer;

— intrinsic temporal variability of preparation treatments (before irradiation and/or before reading), if existing;

— intrinsic temporal variability of reading process;

— degradation due to environmental effects on the preparation treatments, if existing;

— degradation due to environmental effects on the reading process.

This document gives information for extremity dosimetry in the Annex C, based on recommendations given by ICRU Report 66. This document addresses only neutron personal monitoring and not criticality accident conditions.

The links between this document and ISO 21909-2 are given in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 29661, *Reference radiation fields for radiation protection — Definitions and fundamental concepts*

1) This maximal limit of the energy range is only an order of magnitude. The reference radiation fields used for the performance tests are those defined in ISO 8529-1. This means that the maximal energies could only be 14,8 MeV or 19 MeV. This document gives performance requirements to 14,8 MeV which is the typical neutron energy encountered for fusion. For fission spectra, the highest energies are around 20 MeV but the contribution to dose equivalent coming from neutrons with energy higher than 14,8 MeV is negligible.

ISO 21909-2, *Passive neutron dosimetry systems — Part 2: Methodology and criteria for the qualification of personal dosimetry systems in workplaces*

ISO 8529-1, *Reference neutron radiations — Part 1: Characteristics and methods of production*

ISO 8529-2, *Reference neutron radiations — Part 2: Calibration fundamentals of radiation protection devices related to the basic quantities characterizing the radiation field*

ISO 8529-3, *Reference neutron radiations — Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence*

ISO 12789-1, *Reference radiation fields — Simulated workplace neutron fields — Part 1: Characteristics and methods of production*

JCGM 100, *GUM 1995 with minor corrections, Evaluation of measurement, data — Guide to the expression of uncertainty in measurement*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 General terms and definitions

3.1.1
ageing
change with time of physical, chemical or electrical properties of a component or module under specified operating conditions, which could result in degradation of significant performance characteristics

[SOURCE: IEC 60050-393:2007, 393-18-41]

3.1.2
detector
radiation detector
apparatus or substance used to convert incident ionizing radiation energy into a signal suitable for indication and/or measurement

[SOURCE: IEC 60050-394:2007, 394-24-01, modified — The term “detector” has been added as the first preferred term.]

3.1.3
fading
loss of signal under certain circumstances such as storage, transmission, humidity or temperature change

[SOURCE: IEC 60050-393:2007, 393-38-54]

3.1.4
dosemeter
dosimeter
device having a reproducible, measurable response to radiation that can be used to measure the *absorbed dose* (3.2.1) or *dose equivalent* (3.2.3) quantities in a given system

[SOURCE: ISO 12749-2:2013, 5.5]

3.1.5
personal dosemeter
meter designed to measure the *personal dose equivalent (rate)* (3.2.5)

Note 1 to entry: A personal dosemeter can be worn on the trunk (whole-body personal dosemeter), at the extremities (extremity personal dosemeter) or close to the eye lens (eye lens dosemeter).

[SOURCE: ISO 29661:2012, 3.1.21]

3.1.6
dosimetry system
system used for measuring *absorbed dose* (3.2.1) or *dose equivalent* (3.2.3), consisting of dosemeters, measurement instruments and their associated reference standards, and procedures for the system's use

[SOURCE: ISO 12749-4:2015, 3.1.3, modified — Definition slightly reworded.]

3.2 Quantities

3.2.1
absorbed dose
D
differential quotient of $\bar{\varepsilon}$ with respect to m, where $\bar{\varepsilon}$ is the mean energy (ISO 80000-5) imparted by ionizing radiation to matter of mass, m:

$$D = \frac{\mathrm{d}\bar{\varepsilon}}{\mathrm{d}m}$$

Note 1 to entry: The gray is a special name for joule per kilogram, to be used as the coherent SI unit for absorbed dose. 1 Gy = 1 J/kg

$$\bar{\varepsilon} = \int D \, \mathrm{d}m$$

where dm is the element of mass of the irradiated matter.

In the limit of a small domain, the mean specific energy $\bar{z} = \frac{\Delta\bar{\varepsilon}}{\Delta m}$ is equal to the absorbed dose D.

The absorbed dose can also be expressed in terms of the volume of the mass element by:

$$D = \frac{\mathrm{d}\bar{\varepsilon}}{\mathrm{d}m} = \frac{\mathrm{d}\bar{\varepsilon}}{\rho \, \mathrm{d}V}$$

[SOURCE: ISO 80000-10:2019, 10-81.1]

3.2.2
quality factor
Q
factor in the calculation and measurement of *dose equivalent* (item 3.2.3), by which the *absorbed dose* (item 3.2.1) is to be weighted in order to account for different biological effectiveness of radiations, for radiation protection purposes

[SOURCE: ISO 80000-10:2019, 10-82]

3.2.3
dose equivalent
H

product of the absorbed dose D (3.2.1) to tissue at the point of interest and the quality factor Q (3.2.2) at that point:

$$H = DQ$$

Note 1 to entry: The unit of dose equivalent is joule per kilogram (J·kg^{-1}), and its special name is Sievert (Sv).

[SOURCE: ISO 80000-10:2019, 10-83, modified — Note 1 to entry added.]

3.2.4
neutron fluence
Φ
differential quotient of N with respect to a, where N is the number of neutrons incident on a sphere of cross-sectional area a:

$$\Phi = \frac{\mathrm{d}N}{\mathrm{d}a}$$

Note 1 to entry: The unit of neutron fluence is m^{-2}, a frequently unit used is cm^{-2}.

[SOURCE: ISO 80000-10:2019, 10-43, modified — Note 1 to entry added.]

3.2.5
personal dose equivalent
$H_p(\mathrm{d})$
dose equivalent (3.2.3) in soft tissue at an appropriate depth, d, below a specified point on the human body

Note 1 to entry: The unit of personal dose equivalent is joule per kilogram (J·kg^{-1}) and its special name is sievert (Sv).

Note 2 to entry: The specified point is usually given by the position where the individual's dosimeter is worn.

[SOURCE: ICRP 103:2007]

3.2.6
ambient dose equivalent
$H^*(10)$, $H'(0,07)$ or $H'(3)$
dose equivalent (3.2.3) that would be produced by the corresponding aligned and expanded field in the *ICRU sphere* at a depth, d, on the radius opposing the direction of the aligned field

[SOURCE: IAEA – Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - Interim Edition IAEA Safety Standards Series GSR Part 3, 2011]

3.2.7
conversion coefficient
$h_{p\Phi}(10,E,\alpha)$
quotient of the *personal dose equivalent* (3.2.5) *at 10 mm depth*, $H_p(10)$, and the *neutron fluence*, Φ (3.2.4), at a point in the radiation field used to convert neutron fluence into the personal dose equivalent at 10 mm depth in the ICRU tissue slab phantom, where E is the energy of the incident neutrons impinging on the phantom at an angle α

Note 1 to entry: The unit of the conversion coefficient is Sv·m^2. A commonly used unit of the conversion coefficient is pSv·cm^2.

3.3 Calibration and evaluation

3.3.1
arithmetic mean
$\overline{x}$
average of a series of n measurements, x_i, given by the following formula:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

3.3.2
conventional true value for the neutron personal dose equivalent H^{conv}
quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: The conventional value H^{conv} is the best estimate of the quantity to be measured, determined by a primary standard or a secondary or working measurement standard which are traceable to a primary standard.

Note 2 to entry: In this document, the quantity is the neutron personal dose equivalent.

[SOURCE: ISO/IEC Guide 99:2007, 2.12, modified — Term and notes to entry modified.]

3.3.3
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding readings with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Note 1 to entry: Calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: Calibration should not be confused with adjustment of a measuring system, often mistakenly called "self-calibration", or with verification of calibration.

Note 3 to entry: Often, the first step alone in the above definition is perceived as being calibration.

[SOURCE: ISO/IEC Guide 99:2007, 2.39]

3.3.4
calibration factor
N
quotient of the *conventional quantity value* (3.3.2), H^{conv}, divided by the *reading, M* (3.3.14), derived under standard conditions, given by the following formula:

$$N = \frac{H^{conv}}{M}$$

Note 1 to entry: Mathematical functions, in some cases families of functions, can be used to provide calibration factors over a range of conditions. Several different calibration functions can be defined for the same dosimetry system and possibly be used for different conditions of exposure.

3.3.5
calibration quantity
physical quantity used to establish the calibration of the dosemeter

Note 1 to entry: For the purpose of this document, the calibration quantity is the personal dose equivalent at 10 mm depth in the ICRU tissue slab phantom, $H_p(10)$.

3.3.6
standard deviation
s
parameter for a series of *n* measurements, x_i, characterizing the dispersion and given by the following formula:

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

where $\bar{x}$ is the arithmetic mean of the results of *n* measurements.

3.3.7
coefficient of variation
C
ratio of the standard deviation *s* to the arithmetic mean $\bar{x}$ of a set of *n* measurements x_i given by the following formula:

$$C = \frac{s}{\bar{x}} = \frac{1}{\bar{x}}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

[SOURCE: IEC 60050-394, 394-40-14]

3.3.8
minimum recording value
H_{min}
minimum value of dose which is recorded, i.e the lower limit of the dose range, defined by the dosimetry laboratory

Note 1 to entry: H_{min} can be equal to 0,10 mSv or 0,20 mSv or even 0,30 mSv for example. The choice depends on the country of the dosimetry laboratory. Indeed, H_{min} would be logically at least equal or lower to the legal threshold of the country.

Note 2 to entry: In this document, H_{min} cannot exceed 0,3 mSv : $H_{min} \leq 0{,}3$ mSv.

3.3.9
influence quantity
quantity (parameter) that may have a bearing on the result of a measurement without being the subject of the measurement

[SOURCE: ISO 8529-3:1998, 3.2.1, modified – by adding the word “parameter” and removing Note 1 to entry.]

3.3.10
measured dose equivalent
H_M
product of the *reading* (3.3.13), *M*, and the *calibration factor* (3.3.4), *N:*

$$H_M = M \cdot N$$

Note 1 to entry: More elaborate algorithms may also be used.

3.3.11
phantom
object constructed to simulate the scattering and absorption properties of the human body for a given ionizing radiation

Note 1 to entry: For calibrations for whole body radiation protection considerations, the ISO water slab phantom is employed. It is made with polymethyl metacrylate (PMMA) walls (front wall 2,5 mm thick, other walls 10 mm thick), of outer dimensions 30 cm × 30 cm × 15 cm and filled with water.

Note 2 to entry: In the cases of very non-uniform irradiation conditions, an extremity cylinder, pillar or rod phantom may be used as described in ICRU report 66.

[SOURCE: ISO 12749-2, 4.1.6.1 modified — Notes 1 and 2 to entry added.]

3.3.12
reference conditions
set of influence quantities for which the *calibration factor* (3.3.4) is valid without any correction

[SOURCE: ISO 8529-3: 1998, 3.2.2]

3.3.13
reading
M
quantitative indication of a *detector* (3.1.2) or *dosemeter* (3.1.4) when it is read out, generally corrected for background, ageing, fading and non-linearity of the process or the read out system

3.3.14
read out
process of determining the indication of a *detector* (3.1.2) or dosemeter reader

3.3.15
dose equivalent response
response
R
measured dose equivalent (3.3.10), H_M, divided by the *conventional quantity value* (3.3.2) of the dose equivalent, H^{conv}, as given by the following formula:

$$R = \frac{H_M}{H^{\text{conv}}}$$

Note 1 to entry: The reading, M, is converted into dose equivalent, H_M, by multiplying M by an appropriate conversion coefficient or by using a more elaborate algorithm.

Note 2 to entry: In this document, the quantity is personal dose equivalent: $R = \frac{H_{\text{p}}^{M}(10)}{H_{\text{p}}^{\text{conv}}(10)}$

Note 3 to entry: In this document, for the sake of brevity, $H_M = H$ is used.

Note 4 to entry: The reciprocal of the response at *reference conditions* is equal to the calibration coefficient.

Note 5 to entry: In radiation metrology, the term response, abbreviated for this application from “response characteristic” (VIM), is defined as the ratio of the reading, M, of the instrument, to the value of the quantity to be measured by the instrument, for a specified type, energy and direction distribution of radiation. It is necessary, in order to avoid confusion, to state the quantity to be measured, e.g. the “fluence response” is the response with respect to the fluence, the “dose equivalent response” is the response with respect to dose equivalent.

[SOURCE: ISO 8529-3:1998, 3.2.10, modified — Term and definition reworded.]

3.3.16
standard test conditions
conditions represented by the range of values for the *influence quantities* (3.3.9) under which a *calibration* (3.3.3) or a determination of the *response* (3.3.15) is carried out

3.4 List of symbols

The list of the symbols used in this document is given in Table 1.

Table 1 — List of symbols

Symbol	Meaning	Unit
C	Coefficient of variation	—
D	Absorbed dose	Gy
T_{max}^{ageing}	T_2 - T_1	days
T_{max}^{fading}	Maximal period of storage in days between irradiation and read out	days
d	Depth in ICRU 4-element or soft tissue. Recommended depths are 0,07 mm, 3 mm and 10 mm.	mm
H	Dose equivalent	Sv
H_{HD}	Personal dose equivalent whose value is chosen in the following range: $0{,}8\ mSv < H_{HD} < 2\ mSv$	Sv
H_M	Measured dose equivalent	Sv
H_{min}	Minimum recording value	Sv
$H_p(d)$	Personal dose equivalent at a depth d	Sv
$H_p(10)$	Personal dose equivalent at a depth 10 mm	Sv
H_p^{conv}	Personal dose equivalent of the conventional quantity value	Sv
$h_{p\Phi}\ (10;E,\alpha)$	Conversion coefficient	$Sv{\cdot}m^2$
H^{conv}	Conventional quantity value (of a quantity)	Sv
$H_{neutron}^{conv}$	Conventional quantity value for neutron irradiations only	Sv
H_{photon}^{conv}	Conventional quantity value for photon irradiations only	Sv
$H^*(10)$	Ambient dose equivalent at depth 10 mm	Sv
i	Designator for a group subjected to a specific influence quantity	—
j	Designator for a group subjected to a specific dosemeter out of n dosemeters irradiated equally	—
k	Designator for a group subjected to a specific series of irradiation	—
M	Reading	Sv
N	Calibration factor	—
n	Number of dosemeters in one group that are equally irradiated	—
Q	Quality factor	—
R	Response	—
R^{conv}	Reference response	—
r	Permitted value	—
r_{max}	Maximal permitted value	—
r_{min}	Minimum permitted value	—
s	Sample (experimental) standard deviation	—
T_1	Minimum period between the manufacturing date for disposable dosemeter or the day when the reset is done for reusable dosemeters and the first day of possible irradiation	days
T_2	Maximal period between the manufacturing date for disposable dosemeter or the day when the reset is done for reusable dosemeters and last day of possible irradiation	days
t_{n-1}	Student t-factor for n measurements	—
U_{H^M}	Expanded uncertainty of the measured personal dose equivalent	As quantity
$U_{H^{conv}}$	Expanded uncertainty of the conventional true value for the personal dose equivalent	As quantity

Table 1 *(continued)*

Symbol	Meaning	Unit
U_{com}	Expanded uncertainty of a combined quantity of conventional quantity values. This uncertainty is equivalent to the half-width of the confidence interval about the combined quantity at a confidence level of 95 %	As quantity
ϕ	Fluence	m^{-2}
$\bar{x}$	Arithmetic mean	—

This document uses SI units. However, the following units of practical importance for time and energy are used when necessary:

— days (d) and hours (h) for time;

— electron-volt (eV) knowing that 1 eV = 1,602 × 10^{-19} J.

The SI unit of dose equivalent is J·kg^{-1} but the dedicated name for the unit of dose equivalent is Sievert (Sv).

4 General test conditions

4.1 Test conditions

All tests shall be performed under standard test conditions in accordance with Annex D. The actual conditions should be indicated in the test report. These conditions should not undergo significant changes over a series of measurements to preclude the influence on detector signals.

4.2 Reference radiation

The reference radiation fields defined in ISO 8529-1 shall be used. The tests shall be performed with neutrons of several energies:

a) thermal beam as described in ISO 8529-1;

b) mono-energetic beams at 144 keV; 250 keV; 565 keV; 1,2 MeV; 14,8 MeV; 19 MeV described in ISO 8529-1:2021, Table 2;

c) the moderated ^{252}Cf neutron source described in ISO 8529-1:2021, Table 1;

d) ^{241}Am-Be or ^{252}Cf neutron sources.

During the tests, dosimetry systems shall be irradiated on the ISO slab water phantom and under the conditions described in ISO 8529-3 and in ISO 29661 (except for extremity dosemeters - see Annex C).

The performance tests aimed at characterizing the intrinsic properties of the dosimetry system (coefficient of variation, linearity, energy and angular dependence of the response) shall be carried out for different energy distributions (e.g. ^{241}Am-Be or ^{252}Cf neutron sources, mono-energetic fields at different energies). One well-characterized neutron field (e.g., ^{241}Am-Be or ^{252}Cf) is sufficient to assess changes to the characteristics of a dosimetry system due to internal or external conditions (fading, influence of photons, etc.). Apply irradiation conditions defined in Annex E.

The chosen source for irradiations with an ^{241}Am-Be or ^{252}Cf neutron source shall be the same as the one used to calibrate the dosimetry system.

A specific section dedicated to extremity dosimetry is given in Annex C.

NOTE This document does not require tests using simulated workplace neutron fields as defined in ISO 12789-1 because of the very limited availability of facilities delivering such fields.

For dosimetry systems calibrated using in-field calibration, some tests can also be performed in these fields.

5 Test and performance requirements

This document provides performance and test requirements for determining the acceptability of neutron dosimetry systems to be used for the measurement of personal dose equivalent, $H_p(10)$, for neutrons ranging in energy from thermal to 20 MeV.

Tests of the performance of the dosimetry systems are designed to address all conditions in which dosemeters are used. The objective is to test that any dosemeter gives results with sufficient accuracy when going through all the processes in the laboratory (storage, packaging, possible preparative treatments, unpackaging, possible treatments before reading and the read out itself), delivery to the customer and use by the customer in any realistic situation.

This document does not propose tests for the parameters of the systems and processes operated in the laboratory capable of influencing the reproducibility and stability of dosimetric performance, mainly because systems and processes can be strongly dependent on the dosimetric technique used. Nevertheless, the importance of treating this question is stressed, accounting for specifications of the manufacturer and conditions of use in the laboratory. The critical parameters for processing dosemeters shall be described.

The following general requirements apply to the tests for all dosimetry systems:

a) The tests shall be performed on a specified number of dosemeters or a minimum specified number depending on the considered test. These dosemeters shall be randomly selected among dosemeters used in the routine process (i.e., from the population of dosemeters provided to radiation workers);

b) The global processing to store, prepare and analyse the dosemeters shall be performed in accordance with the routine process. More specifically, in case background dosemeters are used to evaluate and to subtract the background noise, these dosemeters shall be used as in the routine procedure;

c) The laboratory shall explain how the total $H_p(10)$ as well as the specific neutron component are determined.

   The tests to perform and the associated requirements to fulfil by the dosimetry systems are divided into two categories:

   1) tests aiming at quantifying the intrinsic characteristics of the dosimetry systems:

      — For the coefficient of variation, apply 7.3 and the criteria given in B.1.

      — For the linearity, apply 7.4 and the criteria given in B.2,

      — For energy and angle dependence of the response, (apply 7.5 and the criteria given in B.3);

   2) The tests aiming at quantifying the changes due to external or internal influence quantities (such as time, temperature, humidity, exposure to radiations other than neutrons, etc.). The tests and criteria aim to ensure the stability of dosimetric performances of the dosimetry systems in the range of realistic conditions of use of the dosemeters: influence of fading, ageing, radiation other than neutrons, harsh climatic conditions, light exposure, physical damage, sealing. Apply Clause 8 and criteria given in Table B.3.

Moreover, before the performance tests, a preliminary optional test is proposed to reduce the number of irradiations. This test, detailed in Clause 6, concerns the qualification for eliminating the use of the full neutron and photon package.

A minimum number of four dosemeters is required for each test except for the test for the coefficient of variation/linearity (see 7.3 and 7.4) and the test for eliminating the use of the full neutron and photon package (see Clause 6). Except for the test for the coefficient of variation/linearity, the number of dosemeters per lot may be increased to be adapted to the associated applied dose. The maximal number of dosemeters should not be higher than 25, except for the test 8.3, where the number can be increased to 50.

The performance requirements are demonstrated to be met to 95 % confidence. Apply Annex F to determine the confidence interval.

6 Qualification for eliminating the use of the full neutron and photon package

6.1 Purpose of the test

This test is not required if the full neutron and photon package is used.

Many configurations of irradiations are required for the performance tests. Moreover, the number of dosemeters per configuration may be significantly high, especially for configurations at the minimum recording value. Neutron dosemeters can be combined with photon dosemeters, working independently, but packaged together. Neutron dosemeters (especially when they are integral with photon dosemeters) can take up a lot of space on the phantom, limiting the number of dosemeters that can be irradiated at one time. The number of dosemeters that can be placed on the phantom per irradiation is limited by the size of the dosemeters. That is why several irradiations may be needed per configuration.

This test is used to characterize the influence of the photon dosemeters and of the package on the response of the neutron dosemeter. If the criterion of this test is met, then the influence of the photon dosemeter and the package on the neutron response can be considered negligible. Then the performance tests described in Clause 7 can be performed using only the neutron component of the combined dosemeter. The overall number of irradiations can then be reduced if the size of the neutron dosemeter is smaller than that of the combined dosemeter.

If this test fails, all the performance tests described in Clause 7 shall be performed with the whole dosemeters (combined photon and neutron components as packaged together).

NOTE Even if the test is passed and criteria fulfilled, the responsible regulatory, licensing or accrediting body cannot accept the procedures described in Clause 6. In such a case, the full neutron and photon package can be mandatory.

For the tests to establish the "stability in the range of realistic conditions of use of the dosemeters" in Clause 8, the package can be considered necessary by the dosimetry laboratory.

6.2 Method of test

Prepare four lots numbered j = 1 to 4 of i = 1 to at least 6 dosemeters. The two first lots are composed of the whole dosemeters and the last two lots are composed of neutron dosemeters only. Irradiate the four lots at a conventional quantity value of personal dose equivalent H_{j}^{0} = 1 mSv, with a ^{241}Am-Be or ^{252}Cf neutron source for lots 1 and 3, and with a mono-energetic neutron beam at 144 keV for lots 2 and 4.

6.3 Interpretation of results

Read out and determine the measured dose equivalent for each dosemeter, $H_{i,j}$. Calculate the arithmetic mean, H_j, and the experimental standard deviation, s_j, for the four lots. Show that the criteria defined by Formulae (1) and (2) are met:

for the irradiations with a ^{241}Am-Be or ^{252}Cf neutron source,

$$0,9 \leq \left[\left(\frac{H_1}{H_3} \right) \pm U_{1,3} \right] \cdot \frac{H_3^{\mathrm{conv}}}{H_1^{\mathrm{conv}}} \leq 1,11 \quad (1)$$

for the irradiations with a mono-energetic neutron beam at 144 keV,

$$0,9 \leq \left[\left(\frac{H_2}{H_4} \right) \pm U_{2,4} \right] \cdot \frac{H_4^{\mathrm{conv}}}{H_2^{\mathrm{conv}}} \leq 1,11 \quad (2)$$

where $U_{m,n}$ is the uncertainty for the quotient of the experimental arithmetic means, H_m and H_n, calculated in accordance with Formula (F.5).

If the criterion of this test is met, the influence on the neutron response of the photon dosemeter and the package is considered negligible. Then, the performance tests may be done using only the neutron dosemeters. If this test fails, all of the performance tests shall be conducted with the photon and neutron dosemeters packed together.

This test could be replaced by a study based on Monte-Carlo calculations, if such method is validated by measurements.

7 Performance tests for the intrinsic characteristics of the dosimetry systems

7.1 General

The tests described in Clause 7 (coefficient of variation/linearity, energy and angular responses) shall be performed for all dosimetry systems.

7.2 Irradiations

To perform the tests characterizing the intrinsic properties of the neutron dosimetry system, several irradiations are required. They are summarized in Table 2. To reduce the number of irradiations, the same irradiation may be used for several tests. For instance, the irradiation with a ^{241}Am-Be or ^{252}Cf source to a conventional quantity value of personal dose equivalent of 1 mSv is used for three tests: linearity, energy and angular tests.

This document does not describe any test for determining the detection threshold by measuring the background signal of unirradiated dosemeters. However, the tests for “coefficient of variation”, “energy dependence of response” and “angle dependence of response” are all performed at two levels of dose: close to the minimum recording value and in the dose range (0,5 mSv to 2 mSv). The criteria applied at these two levels of dose can differ.

Table 2 — Series of irradiation required to perform the tests dedicated to characterize the intrinsic properties of the dosimetry system

Energy range	Thermal energy range			Minimal rated energy range												Fast energy range
Angle of incidence from normal	0°	60°	85°[a]	0°								30°			60°	0°
Series	A	B	Q	C	D	E	F	G	H	I	J	K	L	M	N	O
Dose mSv	Thermal spectra			144 keV	250 keV	565 keV	1,2 MeV	^{252}Cf or ^{241}Am-Be with a 144 keV or 250 keV field (in dose $H_p(10)$ proportion of 50 %)	^{252}Cf or ^{241}Am-Be with a thermal field (in dose $H_p(10)$ proportion of 25 % to 50 %)	Moderated ^{252}Cf	^{252}Cf or ^{241}Am-Be (or any energy between 2 and 10 MeV for linearity)	144 keV	250 keV	^{252}Cf or ^{241}Am-Be (or any energy between 2 and 10 MeV for linearity)	^{252}Cf or ^{241}Am-Be (or any energy between 2 and 10 MeV for linearity)	Between 10 MeV and 19 MeV
H_{min}	ET LT				ET					ET	ET LT			AT		
H_{min} + 0,1 mSv	ET LT	AT		ET	ET	ET	ET	ET	ET	ET	ET LT	AT	AT	AT	AT[c]	ET
0,5	ET LT[b]	AT[b]	AT[a]								LT					
0,8 mSv < H_{HD}[d] < 2 mSv	ET[b]	AT[b]		ET	ET	ET	ET	ET	ET	ET	ET LT	AT	AT	AT	AT	ET
2	LT[b]										LT					
5											LT					
10											LT					
20											LT					

NOTE The irradiations used for each test are represented by a specific sign: LT for the test of coefficient of variation/linearity, AT for the angular (≠0) test and ET for the energy test.

[a] For thermal neutrons, a specific test is done at 85°, for dose above 0,5 mSv, to check if the reading of the dosemeter at this angle is not higher by a factor of 3 (+200 %) than the reading of the dosemeter at 0°, irradiated by the same fluence of thermal neutrons. This is requested to check a problem which could exist because of a lack of shielding on the side of the dosemeter. The irradiation is performed at the maximal level of dose of the series A. Moreover, the neutron fluence corresponding to $H_p(10,0°)$ as used in series A should be taken for irradiation.

[b] All these irradiations are optional depending of the maximal dose value stated in the accompanying documentation for the thermal field. If the maximal stated value is at least 0,8 mSv, then energy and angular tests do not have to be done at 0,5 mSv.

[c] irradiation required but criteria just informative. The test has to be performed and the result given.

[d] The abbreviation HD means 'high dose', *high* in comparison to H_{min}. Indeed, the performance tests for the neutron dosemeters shall be performed both at low level of dose near H_{min} and at a higher one H_{HD}.

H_{HD} corresponds to a conventional quantity value of personal dose equivalent chosen in the range: 0,8 mSv < H_{HD} < 2 mSv. Defining a range of dose instead of an exact conventional quantity value of personal dose equivalent of 1 mSv is preferred. The laboratory in charge of the irradiations or in charge of the characterization of the dosimetry system shall choose a value included in this range, which would not be known by the dosimetry laboratory.

H_{min} corresponds to the minimum value of dose which is reported. H_{min} is then the lower limit of the dose range, defined by the dosimetry laboratory. H_{min} would be logically at least equal to or lower than the legal threshold required in each jurisdiction (0,10; 0,20 or 0,30 mSv, for example). To comply with this document, H_{min} shall be equal to 0,3 mSv at maximum:

The criteria of the different tests, coefficient of variation, linearity, energy and angle dependences of the response, are functions of the value of the chosen H_{min}. The value of H_{min} should be specified in the accompanying documentation.

Although H_{min} corresponds to the minimum value of dose which is reported, the value of the personal dose equivalent below this value should not be truncated, contrary to how it is done in the routine process.

As the thermal and fast energy ranges are optional, the dosimetry laboratory shall clearly state in the documentation the energy range in which the dosimetry system is characterized:

a) thermal + minimal rated energy ranges;

b) minimal rated energy range only;

c) minimal rated + fast energy ranges;

d) thermal + minimal rated + fast energy ranges.

For dosimetry systems whose stated range does not include thermal energies, regardless whether the thermal neutron contribution to dose equivalent is considered negligible, the performance should demonstrate that the dosimetry system response to thermal neutrons does not adversely influence the determination of dose equivalent result from higher energy neutrons. The mandatory "H" irradiation series has been designed for that purpose (see Table 2) for all dosemeters.

Table 3 — Mandatory series of irradiation as a function of the stated energy range of the dosimetry systems

Stated energy range of the dosimetry systems	Mandatory series of irradiation
Thermal + minimal rated energy ranges	(A, B, Q) + (C, D, E, F, G, H, I, J, K, L, M, N)
Minimal rated energy range only	(C, D, E, F, G, H, I, J, K, L, M, N)
Minimal rated + fast energy ranges	(C, D, E, F, G, H, I, J, K, L, M, N) + (O)
Thermal + minimal rated + fast energy ranges	(A, B, Q) + (C, D, E, F, G, H, I, J, K, L, M, N) + (O)

Table 3 gives the mandatory series of irradiations as a function of the stated energy range of the dosimetry systems.

The maximum dose, 2 mSv, for thermal neutron tests is proposed in order to take into account the reality of the potential exposures with thermal neutrons and the dose rates of the available reference thermal fields. This may also be adapted according to the dosimetry laboratory. This maximal value should be stated in the accompanying documentation. However, this maximal value cannot be lower than H_{min} + 0,1 mSv.

In case of irradiations with neutrons at non-normal incidence, the angle of incidence for the n irradiations is varied positive and negative in two planes perpendicular to each other and to the plane of the dosemeter. It means, in case of n = 8, that two dosemeters are irradiated in each case to the same angle of incidence. This variation is not necessary in cases where the dosemeter design is symmetrical in its essential sensitive parts and this is stated by the manufacturer.

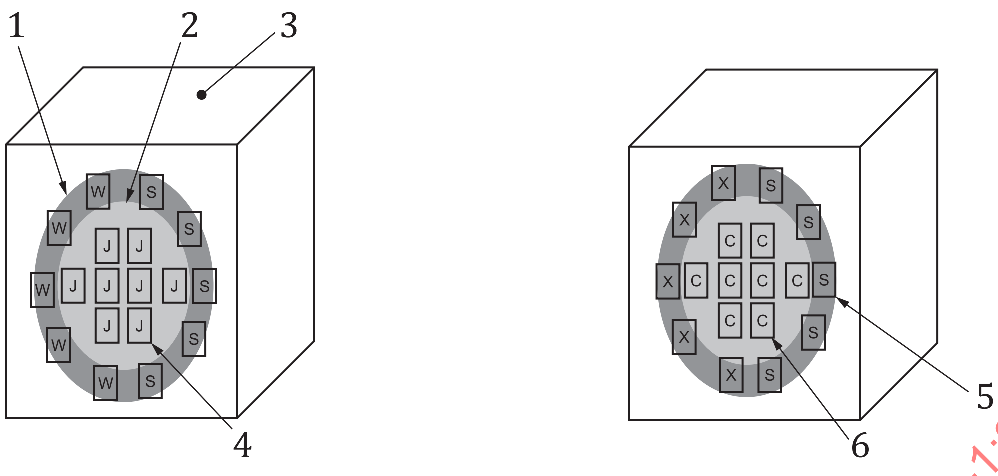
For each of the mandatory series of irradiation functions of the stated energy ranges of the dosimetry system, prepare *j* lots (*j* corresponding to the number of dose values given in Table 2) of *i* = 1 to at least 4 dosemeters and irradiate them with neutrons of energy and angle, as stated in Table 2, to the conventional quantity value of personal dose equivalents, $H_{k,j}^{\text{conv}}$, as given in the first column of Table 2.

In the cases of the series "G", mixed-field irradiations are performed with half of the dose delivered by a radionuclide source (^{252}Cf or ^{241}Am-Be) and half of the dose delivered by low-energy (144 keV or 250 keV).

In the cases of the series "H", mixed-field irradiations are performed with a radionuclide source (^{252}Cf or ^{241}Am-Be) and with thermal neutrons. In that case, the proportion of the dose equivalent contributed from the irradiation using the thermal field is to be between 25 % to 50 % of the total dose equivalent.

To limit the number of irradiations and to take into account mixed field situations, dosemeters could be irradiated at the border of the allowed usual surface of irradiation of the phantom and half of them would be irradiated in both fields of the mixed field and half only in one of the fields, then adding values of that last dosemeters (see Figure 1). In Figure 1, the dosemeters "W" are irradiated to an ^{241}Am-Be or ^{252}Cf source, the dosemeters "X" to 144 keV neutron field and the dosemeters "S" to these two fields, because they are present on the phantom for the two irradiations. Then, using this practical method of irradiations, the additivity could be checked.

Using the same methodology, a test in a mixed field (mandatory + thermal) is proposed to detect nonlinearity of algorithm and over response of dosemeters for thermal neutrons. In the case of simultaneous irradiation of several dosemeters on a phantom, effects as described in ISO 29661 (inscattered neutrons from adjacent dosemeters, changes in the properties of the backscattered field) need special attention and can lead to a reduction of the number of dosemeters irradiated together. In this specific situation, the dosemeters exposed to the mixed field corresponding to the column 'H' in Table 2 could be the sum of the irradiation perform to the fields corresponding to column 'A' and 'J' in Table 2.



a) **First irradiation**[a]   b) **Second irradiation**[b]

Key

1 border of the allowed usual surface of irradiation
2 allowed usual surface of irradiation
3 phantom
4 dosemeters used for the irradiation J
5 dosemeters used for the test of mixing two different fields: "W + X = S"
6 dosemeters used for the irradiation C

a All dosemeters irradiated with an ^{241}Am-Be or ^{252}Cf neutron source.
b All dosemeters irradiated with a 144 keV monoenergetic field.

NOTE The positions and number of dosemeters are just given for example.

Figure 1 — Principle of optimization of the irradiations that could be performed to take into account mixed field situations

Figure 1 illustrates the case with the mixed field 144 keV (irradiation 'C' in Table 2) + bare source (irradiation 'J' in Table 2), but this method could be enlarged to all different mixed fields.

7.3 Coefficient of variation

7.3.1 General

This test is used to determine whether the statistical fluctuations of the indicated value is acceptable from low to high dose exposures. The test shall be performed with 12 dosemeters for doses below 0,5 mSv and 6 dosemeters for doses ≥0,5 mSv.

7.3.2 Method of test

Read out the i = 12 dosemeters for doses below 0,5 mSv and 6 dosemeters for doses ≥0,5 mSv of the lots corresponding to the k series of irradiations named "A" and "J" in Table 2.

For every conventional dose, $H_{k,j}^{\mathrm{conv}}$, determine the measured dose equivalent, $H_{k,j,i}$. Calculate the arithmetic mean, $H_{k,j}$, for each lot, j, of each series, k, and the respective experimental standard deviation, $s_{k,j}$.

7.3.3 Interpretation of results

The coefficient of variation, $C_{k,j} = \frac{s_{k,j}}{H_{k,j}}$, of the 12 dosemeters for doses below 0,5 mSv or 6 dosemeters above 0,5 mSv for each series, shall meet Formula (3):

$$\frac{s_{k,j}}{H_{k,j}} < r_{\max} \tag{3}$$

with $r_{\max}$ defined in B.1.

7.4 Linearity

7.4.1 General

This test is used to determine whether the dose response is acceptable from low to high dose exposures. The test shall be performed with 12 dosemeters for doses below 0,5 mSv and 6 dosemeters for doses ≥0,5 mSv.

7.4.2 Method of test

Read out the i = 12 dosemeters for doses below 0,5 mSv and 6 dosemeters for doses ≥0,5 mSv of the lots corresponding to the k series of irradiations named “A” and “J” in Table 2.

For every conventional dose $H_{k,j}^{\text{conv}}$, determine the measured dose equivalent, $H_{k,j,i}$. Calculate the arithmetic mean, $H_{k,j}$, for each lot j of each series k. Calculate the response $R_{k,j} = H_{k,j}/H_{k,j}^{\text{conv}}$. Then, determine the mean response R_k of all the calculated response values for each series.

7.4.3 Interpretation of results

A reference response is defined as the response obtained for the irradiations within the range [0,8 mSv, 2 mSv] and calculated according to Formula (4):

$$R_k^{\text{reference}} = \frac{H_{k,[0,8:2]\text{mSv}}}{H_{k,[0,8:2]\text{mSv}}^{\text{conv}}} \tag{4}$$

Then, for each series, the response $R_{k,j}$ is calculated using Formula (5):

$$R_{k,j} = \frac{H_{k,j}}{H_{k,j}^{\text{conv}}} \tag{5}$$

The response $R_{k,j}$ divided by the reference response $R_k^{\text{reference}}$ shall not exceed the values given in Table B.1, as mentioned in Formula (6):

$$r_{\min} - \frac{U_{\text{com}}}{R_k^{\text{reference}}} \leq \frac{R_{k,j}}{R_k^{\text{reference}}} \leq r_{\max} + \frac{U_{\text{com}}}{R_k^{\text{reference}}} \tag{6}$$

with $r_{\min}$ and $r_{\max}$ defined in Table B.1, where U_{com} is the uncertainty related to the measurements of the personal dose equivalent $H_{k,j}$ for the combined quantity, $\frac{R_{k,j}}{R_k^{\text{reference}}}$, calculated in accordance with Annex F.

7.5 Energy and angle dependence of the response

7.5.1 General

This test uses the series of irradiations defined in Table 2 corresponding to the energy and angle ranges in which the dosimetry system shall be characterized (see Table 3).

Conformity with the requirements of this test may be impractical for dosimetry systems with strong variable energy dependence of response, as with some thermoluminescent albedo dosemeters, for instance, for which a qualification shall be completed directly at the workplaces in which they are used.

If this test is not fulfilled by the dosimetry system, this dosimetry system shall be qualified at the work situations where it is used. For this purpose, ISO 21909-2 shall be used, in addition to the tests and requirements of this document.

7.5.2 Method of test

Read out each dosemeter of the lots of all the series of irradiations, corresponding in Table 2 either to the energy test (tests noted “ET” in Table 2) or the angle of incidence test (tests noted “AT”). Determine the measured dose equivalent, $H_{k,j,i}$, and calculate the arithmetic mean, $\overline{H}_{k,j}$, for each lot j of each series k and the respective experimental standard deviations, $s_{k,j}$.

7.5.3 Interpretation of results

For each lot and for dose $H_{k,j}^{\text{conv}}$, equal to H_{min}, H_{min} + 0,1 mSv and H_{HD}, the Formula (7) shall be met:

$$r_{\text{min}} - U_{\text{rel},k,j}^{\text{conv}} \leq \left[\left(\frac{\overline{H}_{k,j}}{H_{k,j}^{\text{conv}}} \right) \pm U_{k,j} \right] \leq r_{\text{max}} + U_{\text{rel},k,j}^{\text{conv}} \quad (7)$$

where

r_{min} is defined in Table B.2 and illustrated in Figure B.2;

r_{max} is defined in Table B.2 and illustrated in Figure B.2;

$U_{k,j}$ is the uncertainty for the combined quantity in brackets, $\left(\frac{\overline{H}_{k,j}}{H_{k,j}^{\text{conv}}} \right)$, calculated in accordance with Formula (F.5);

$U_{\text{rel},k,j}^{\text{conv}}$ is the relative uncertainty related to the conventional quantity value of the personal dose equivalent.

7.6 Specific test for thermal neutrons

7.6.1 General

This test is used to determine whether the dose value from the dosemeter differs from the conventional true quantity by more than a factor of 3 (+200 %) at 85°, compared to reading at normal incidence, for thermal neutrons and for doses above 0,5 mSv. This test shall be performed by dosimetry laboratories which have stated that thermal energies are encompassed by the energy range of their dosimetry system.

7.6.2 Method of test

Read out each dosemeter of the lot corresponding to the series of irradiations named "Q" in Table 2. Determine the measured dose equivalent, $H_{Q,i}$, and calculate the arithmetic mean, $\overline{H}_Q$, and the respective experimental standard deviations, s_P.

Read out each dosemeter of the lot corresponding to the series of irradiations named "A" in Table 2 and the personal dose equivalent H_{HD}. Determine the measured dose equivalent, $H_{A,i}$, and calculate the arithmetic mean, $\overline{H}_A$ and the respective experimental standard deviations, s_A.

7.6.3 Interpretation of results

Formula (8) shall be met:

$$\left[\left(\frac{\overline{H}_Q}{\overline{H}_A}\right) \pm U_{Q,A}\right] \cdot \frac{H_A^{conv}}{H_Q^{conv}} \leq 3 \tag{8}$$

where $U_{Q,A}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8 Performance tests for stability in the range of realistic conditions of use of the dosemeters

8.1 Fading

8.1.1 General

If a loss of signal could appear during a long period of storage after irradiation, a correction function might be needed to avoid strong effect on the dose determination. This test is used to determine whether the potential loss of signal from storage is correctly accounted.

Define the maximal period of storage in days between irradiation and read out, noted T_{max}^{fading}. For example, for a wearing period of three months and a maximal storage in the laboratory before reading of one month, T_{max}^{fading} is equal to four months, i.e. 120 days.

8.1.2 Method of test

Prepare two lots of i = 1 to at least 4 dosemeters (25 dosemeters at maximum). Irradiate these lots with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of personal dose equivalent, H^{conv}, between 1 mSv and 3 mSv on day, T_0.

Process the first lot of dosemeters in two weeks just following the irradiation. Store and keep dosemeters of the second lot under normal test conditions. Process them on day $T_0 + T_{max}^{fading} + 1$.

Read out each dosemeter, determine the measured dose equivalent for each dosemeter, $H_{j,i}$, and calculate the arithmetic mean $\overline{H}_j$ for each lot and the standard deviation, s_j.

8.1.3 Interpretation of results

The Formula (9) shall be met:

$$0,85 \leq \left[\left(\frac{H_2}{H_1} \right) \pm U_{2,1} \right] \cdot \frac{H_1^{\text{conv}}}{H_2^{\text{conv}}} \leq 1,18 \tag{9}$$

where $U_{2,1}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8.2 Ageing

8.2.1 General

A modification of the response may appear after a long period of storage before irradiation. A correction function may then be needed to avoid strong effect on the dose determination. This test is used to determine whether the modification of response is correctly accounted.

To determine the maximal period of storage before irradiation, noted $T_{\text{max}}^{\text{ageing}}$, determine the following two periods, T_1 and T_2:

— T_1: minimum period between the manufacturing date for disposable dosemeter or the day when the reset is done for reusable dosemeters and the first day of possible irradiation;

— T_2: maximal period between the manufacturing date for disposable dosemeter or the day when the reset is done for reusable dosemeters and last day of possible irradiation.

Then, calculate $T_{\text{max}}^{\text{ageing}} = T_2 - T_1$.

If the manufacturing date is not known, the uncertainty on this date should be taken into account in a conservative way.

8.2.2 Method of test

Prepare two lots of i = 1 to at least 4 dosemeters (25 dosemeters at maximum). The first lot of dosemeters corresponds to dosemeters stored in standard test conditions in the laboratory for T_1 days. Irradiate this lot with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of the personal dose equivalent, H_1^{conv}, between 1 mSv and 3 mSv. Process this first lot of dosemeters two weeks just after the irradiation.

Choose a second lot of dosemeters stored in standard test conditions for T_2 days. Irradiate this lot with a ^{241}Am-Be or ^{252}Cf neutron source to the same conventional quantity value of the personal dose equivalent, H_2^{conv}.

Read out, determine the measured dose equivalent for each dosemeter, $H_{j,i}$, and calculate the arithmetic mean, H_j, and the experimental standard deviation, s_j for lots 1 and 2.

8.2.3 Interpretation of results

Formula (10) shall be met:

$$0,85 \leq \left[\left(\frac{H_2}{H_1} \right) \pm U_{2,1} \right] \cdot \frac{H_1^{\text{conv}}}{H_2^{\text{conv}}} \leq 1,18 \tag{10}$$

where $U_{2,1}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8.3 Effect of storage for unexposed dosemeters

8.3.1 General

This test is used to determine whether there is a strong influence of the ageing on the background signal of the dosemeters.

8.3.2 Method of test

Define the maximal period, T_{max}, between manufacturing time of the detector or the day when reusable dosemeters were reset or zeroed and the first day of use.

Store a lot of at least 10 dosemeters, which are unirradiated, under standard test conditions during T_{max}. Read out and determine the measured dose equivalent for each dosemeter, H.

NOTE The number of dosemeters can be increased, if wanted by the laboratory.

8.3.3 Interpretation of results

A maximum of 20 % of the unirradiated dosemeters shall present a measured dose equivalent H_M higher than H_{min}. Moreover, no dosemeter shall present a measured dose equivalent H_M higher than H_{min} + 0,1 mSv.

If one or more dosemeters present a measured dose equivalent H_M higher than H_{min} + 0,1 mSv, a second test with a lot of 50 dosemeters is necessary: a maximum of one dosemeter shall present a measured dose equivalent H_M higher than H_{min} + 0,1 mSv.

8.4 Exposure to radiation other than neutrons

8.4.1 General

Two tests shall be performed for all dosimetry systems to check whether the system is sensitive to radon or photon radiation. If so, complementary tests are required to characterize more precisely the influence of these two types of radiations on the dose response.

8.4.2 Photon radiation

8.4.2.1 All dosimetry systems

8.4.2.1.1 General

This test applies to all dosimetry systems. This test is used to determine whether the neutron dose equivalent result is significantly influenced by photon radiation.

If this test is passed, then the dosimetry system is not considered to be sensitive to photons.

If this test is not passed, complementary tests shall be performed (see 8.4.2.2).

8.4.2.1.2 Method of test

Prepare two lots numbered j = 1 and 2 of i = 1 to at least 4 dosemeters (25 dosemeters at maximum) and irradiate the first lot with a ^{137}Cs or a ^{60}Co source to a conventional quantity value of the personal dose equivalent, H^{conv}, 10 mSv. Store lot 2 under standard test conditions.

Read out and determine the measured neutron personal dose equivalent for each dosemeter, $H_{j,i}$. Calculate the arithmetic mean $\bar{H}_j$ for each of the two lots and the experimental standard deviation, s_j.

8.4.2.1.3 Interpretation of results

Formula (11) shall be met:

$$\left|\left(\overline{H_1} - \overline{H_2}\right)\right| \pm U_{1,2} \leq H_{min} \tag{11}$$

where $U_{1,2}$ is the uncertainty for the difference of the arithmetic means, calculated in accordance with Formula (F.5).

8.4.2.2 Photon-sensitive dosimetry systems only

8.4.2.2.1 General

For photon-sensitive dosemeters, supplementary performance tests shall be done and these dosemeters shall comply with the tests as described in 8.4.2.2.2 and 8.4.2.2.3.

8.4.2.2.2 Method of test

Prepare three series named k = R, S and T of two lots numbered j = 1 and 2 of i = 1 to at least 4 dosemeters (25 dosemeters at maximum). Irradiate all the dosemeters with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of the personal dose equivalent, $H_{neutron}^{conv}$ of 0,5 mSv for series “R”, 1 mSv for series “S” and 2 mSv for series “T”.

In addition, irradiate the second lot of each series with a ^{137}Cs or a ^{60}Co source to a conventional quantity value of the personal dose equivalent, H_{photon}^{conv} of 1,5 mSv for series “R”, 1 mSv for series “S” and 0,6 mSv for series “T”.

Table 4 gives a summary of the required irradiations.

Table 4 — Performance tests for photon-sensitive dosemeters

Series	Neutron irradiation	Photon irradiation
	$H_{neutron}^{conv}$ mSv	H_{photon}^{conv} mSv
R	0,5	1,5
S	1	1
T	2	0,6

Read out and determine the measured dose equivalent for each dosemeter, $H_{k,j,i}$, calculate the arithmetic mean $\overline{H_{k,j}}$ and the experimental standard deviation, $s_{k,j}$, for the six lots.

8.4.2.2.3 Interpretation of results

Formula (12) shall be met for each series k:

$$\left|\overline{H_{2,k}} - \overline{H_{1,k}}\right| \pm U_{1,2,k} \leq 0{,}1 \text{ mSv} \tag{12}$$

where $U_{1,2,k}$ is the uncertainty for the difference of the arithmetic means, calculated in accordance with Formula (F.5).

8.4.3 Radon

8.4.3.1 Method of test

This test should be performed with the whole dosemeter (full package), as it is usually worn by the worker. Prepare two lots numbered j = 1 and 2 of i = 1 of at least 4 dosemeters (25 dosemeters at maximum) and expose lot 1 to 3 MBq·h/m^3 of radon at 50 % equilibrium with daughters (F = 0,5). Store lot 2 in standard test conditions with no radon in excess of background.

Read out, determine the measured dose equivalent for each dosemeter, $H_{j,i}$, and calculate the arithmetic mean, $\overline{H_j}$, for each of the two lots and the respective experimental standard deviations, s_j.

8.4.3.2 Interpretation of results

Formula (13) shall be met:

$$\left|\left(\overline{H_1}-\overline{H_2}\right)\right| \pm U_{1,2} \leq 0{,}5 \text{ mSv} \tag{13}$$

where $U_{1,2}$ is the uncertainty for the difference of the arithmetic means, calculated in accordance with Formula (F.5).

8.5 Stability under various climatic conditions

8.5.1 General

The dosemeters could be exposed to many different climatic conditions at workplaces not controlled by the dosimetry laboratories. This test is used to determine whether the response of the dosimeter is adversely influenced in harsh environmental conditions. It gives requirements in more stringent conditions than those in which the dosemeter is used.

It is not mandatory to fulfil the criteria of this test but, if the requirements are not fulfilled, the laboratory shall specify to customers the uncertainty added to the dose estimation in these conditions of exposure.

8.5.2 Effect on the dose equivalent response

8.5.2.1 General

This test is used to characterize the stability of the response of the dosimetry system as a function of climatic conditions.

8.5.2.2 Method of test

Prepare three lots numbered j = 1, 2 and 3 of i = 1 to at least 4 dosemeters (25 dosemeters at maximum). Store lot 3 in standard test conditions. Irradiate lot 1 with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of the personal dose equivalent, H^{conv}, between 1 mSv and 3 mSv. Store both lots 1 and 2 of dosemeters in a climatic chamber in which the temperature is 40 °C ± 2 °C and the relative humidity is at least 90 %. After a continuous period of 48 h, remove both lots of dosemeters from the climatic chamber. Irradiate lots 2 and 3 to the same conventional quantity value of the personal dose equivalent as lot 1.

Read out and determine the measured dose equivalent for each dosemeter, $H_{j,i}$, and calculate the arithmetic mean, $\overline{H_j}$, for each of the two lots and the respective experimental standard deviations, s_j.

8.5.2.3 Interpretation of results

Formulae (14) and (15) shall be met:

$$0,85 \leq \left[\left(\frac{H_1}{H_3} \right) \pm U_{1,3} \right] \cdot \frac{H_3^{\text{conv}}}{H_1^{\text{conv}}} \leq 1,18 \tag{14}$$

$$0,85 \leq \left[\left(\frac{H_2}{H_3} \right) \pm U_{2,3} \right] \cdot \frac{H_3^{\text{conv}}}{H_2^{\text{conv}}} \leq 1,18 \tag{15}$$

where $U_{m,n}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8.5.3 Effect for unexposed dosemeters

8.5.3.1 General

This test is used to determine whether harsh climatic conditions adversely influence the background signal of the dosemeters.

8.5.3.2 Method of test

Store a lot of 10 dosemeters, which are unirradiated, in a climatic chamber in which the temperature is 40 °C ± 2 °C and the relative humidity is at least 90 %. After a continuous period of 48 h, remove this lot of dosemeters from the climatic chamber. Read out and determine the measured dose equivalent for each dosemeter, H.

NOTE The number of dosemeters can be increased to 20, if wanted by the laboratory.

8.5.3.3 Interpretation of results

A maximum of 20 % of the dosemeters (2 dosemeters for a total of 10 dosemeters, 4 dosemeters for a total of 20 dosemeters) shall present a measured dose equivalent higher than H_{min}. In addition, no dosemeter shall present a measured dose equivalent higher than H_{min} + 0,1 mSv.

8.6 Effect of light exposure (sensitivity to light)

8.6.1 Effect on the dose response

8.6.1.1 General

This test is used to determine whether the neutron signal is adversely influenced by visible light.

8.6.1.2 Method of test

Prepare two lots numbered j = 1 and 2 of i = 1 to at least 4 dosemeters (25 dosemeters at maximum) and irradiate them with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of the personal dose equivalent, H^{conv}, of at least 1 mSv and 3 mSv. Store the dosemeters of lot 1 in the dark for one week. Expose lot 2 to 1 000 W/m^2 of light for one week, in an otherwise identical environment. The light source should not modify the ambient temperature that should remain below 30 °C.

Read out and determine the measured dose equivalent for each dosemeter, $H_{j,i}$, and calculate the arithmetic mean, H_j, for each of the two lots and the respective experimental standard deviations, s_j, for the two lots.

8.6.1.3 Interpretation of results

Formula (16) shall be met:

$$0{,}85 \leq \left[\left(\frac{H_2}{H_1} \right) \pm U_{2,1} \right] \cdot \frac{H_1^{\text{conv}}}{H_2^{\text{conv}}} \leq 1{,}18 \qquad (16)$$

where $U_{1,2}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8.6.2 Effect for unexposed dosemeters

8.6.2.1 General

This test is used to determine whether exposure to visible light adversely influences the background signal of the dosemeters.

8.6.2.2 Method of test

Expose a lot of 10 dosemeters, which are unirradiated, to 1 000 W/m^2 of light for one week.

The light source should not modify the ambient temperature that should remain below 30 °C.

Read out and determine the measured dose equivalent for each dosemeter, H.

NOTE The number of dosemeters can be increased to 20, if wanted by the laboratory.

8.6.2.3 Interpretation of results

A maximum of 20 % of the dosemeters (2 dosemeters for a total of 10 dosemeters, 4 dosemeters for a total of 20 dosemeters) shall present a measured dose equivalent higher than H_{min}. In addition, no dosemeter shall present a measured dose equivalent higher than H_{min} + 0,1 mSv.

8.7 Drop test

8.7.1 Effect on the dose response

8.7.1.1 General

This test is used to determine whether there is a change in the dosemeter response to neutrons due to physical damage.

8.7.1.2 Method of test

Prepare two lots numbered j = 1 and 2 of i = 1 to at least 4 dosemeters (25 dosemeters at maximum) and irradiate them with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of the personal dose equivalent, H^{conv}, between 1 mSv and 3 mSv. Then drop the dosemeters of the second lot on a representative floor of the working area from a height of 1 m.

Read out each dosemeter and determine the measured dose equivalent, $H_{j,i}$. Calculate the arithmetic mean, $\overline{H}_j$, and the respective experimental standard deviations, s_j, for the two lots.

8.7.1.3 Interpretation of results

Formula (17) shall be met:

$$0{,}85 \leq \left[\left(\frac{H_2}{H_1} \right) \pm U_{2,1} \right] \cdot \frac{H_1^{\text{conv}}}{H_2^{\text{conv}}} \leq 1{,}18 \quad (17)$$

where $U_{1,2}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8.7.2 Effect for unexposed dosemeters

8.7.2.1 General

This test is used to determine the influence of physical damage on the background signal of the dosemeters.

8.7.2.2 Method of test

Drop a lot of 10 dosemeters, which are unirradiated, on a representative floor of the working area from a height of 1 m. Read out and determine the measured dose equivalent for each dosemeter, H.

NOTE The number of dosemeters can be increased to 20, if wanted by the laboratory.

8.7.2.3 Interpretation of results

A maximum of 20 % of the dosemeters (2 dosemeters for a total of 10 dosemeters, 4 dosemeters for a total of 20 dosemeters) shall present a measured dose equivalent higher than H_{min}. In addition, no dosemeter shall present a measured dose equivalent higher than H_{min} + 0,1 mSv.

8.8 Distance to the phantom

8.8.1 General

This test is used to determine the influence of the distance between the phantom front face and back face of the dosemeter on the dosemeter neutron response.

8.8.2 Method of test

Prepare 2 lots of i = 1 to at least 4 dosemeters (25 dosemeters at maximum). Irradiate these lots with a ^{241}Am-Be or ^{252}Cf neutron source to a conventional quantity value of the personal dose equivalent, H^{conv} between 1 mSv and 3 mSv. The dosemeters of the second lot are placed 0,5 cm in front of the phantom surface.

Process the two lots of dosemeters.

Read out each dosemeter, determine the measured dose equivalent for each dosemeter, $H_{j,i}$, and calculate the arithmetic mean, H_j, for each lot and the standard deviation, s_j.

8.8.3 Interpretation of results

Formula (18) shall be met:

$$0{,}85 \leq \left[\left(\frac{H_2}{H_1} \right) \pm U_{2,1} \right] \cdot \frac{H_1^{\mathrm{conv}}}{H_2^{\mathrm{conv}}} \leq 1{,}18 \tag{18}$$

where $U_{1,2}$ is the uncertainty for the quotient of the arithmetic means, calculated in accordance with Formula (F.5).

8.9 Sealing

The manufacturer shall state the precautions to be taken to prevent the ingress of moisture. The effectiveness of the sealing and the associated precautions should be demonstrated by the manufacturer.

9 Identification and accompanying documentation

9.1 Individual marking

Dosemeters and detectors shall have simple, unique and secure means of identification. The marking shall not damage the useful portion of the detector, either directly or indirectly, nor shall it change its behaviour in any significant manner. Dosemeters shall carry any necessary markings for determining their origin, expiration date (if relevant). Moreover, dosemeters shall be marked stating that they are intended for neutron dosimetry and front/back side should be clearly labelled.

9.2 Collective marking

The following information shall be indicated on each box (or other collective packing) of detectors or dosemeters or, failing this, on an accompanying note:

— name or trademark of the manufacturer;

— complete designation;

— serial number or manufacturer's batch number;

— expiration date, if relevant.

9.3 Accompanying documentation

The note attached to each box or other packing container shall include at least the following information, if it is not provided on the container:

— complete designation;

— name and trademark of manufacturer;

— neutron energy range for which the detectors or dosemeters are designed;

— dose range:

— minimum recording value;

— upper limit;

— energy range in which the dosimetry system is characterized:

    — thermal + minimal rated energy ranges;

    — or, minimal rated energy range only;

  - or, minimal rated + fast energy ranges;
  - or, thermal + minimal rated + fast energy ranges;
- method of processing;
- maximal dose at which the dosimetry system is characterized with thermal beam.

The Individual Monitoring Service shall specify in its documentation whether the dosimetry system complies or not with requirements of this document in terms of energy and angular behaviour. If the dosimetry system is not in conformity, then more information shall be added into the documentation (see ISO 21909-2:2021, Clause 4).

Annex A
(informative)

Links between this document and ISO 21909-2

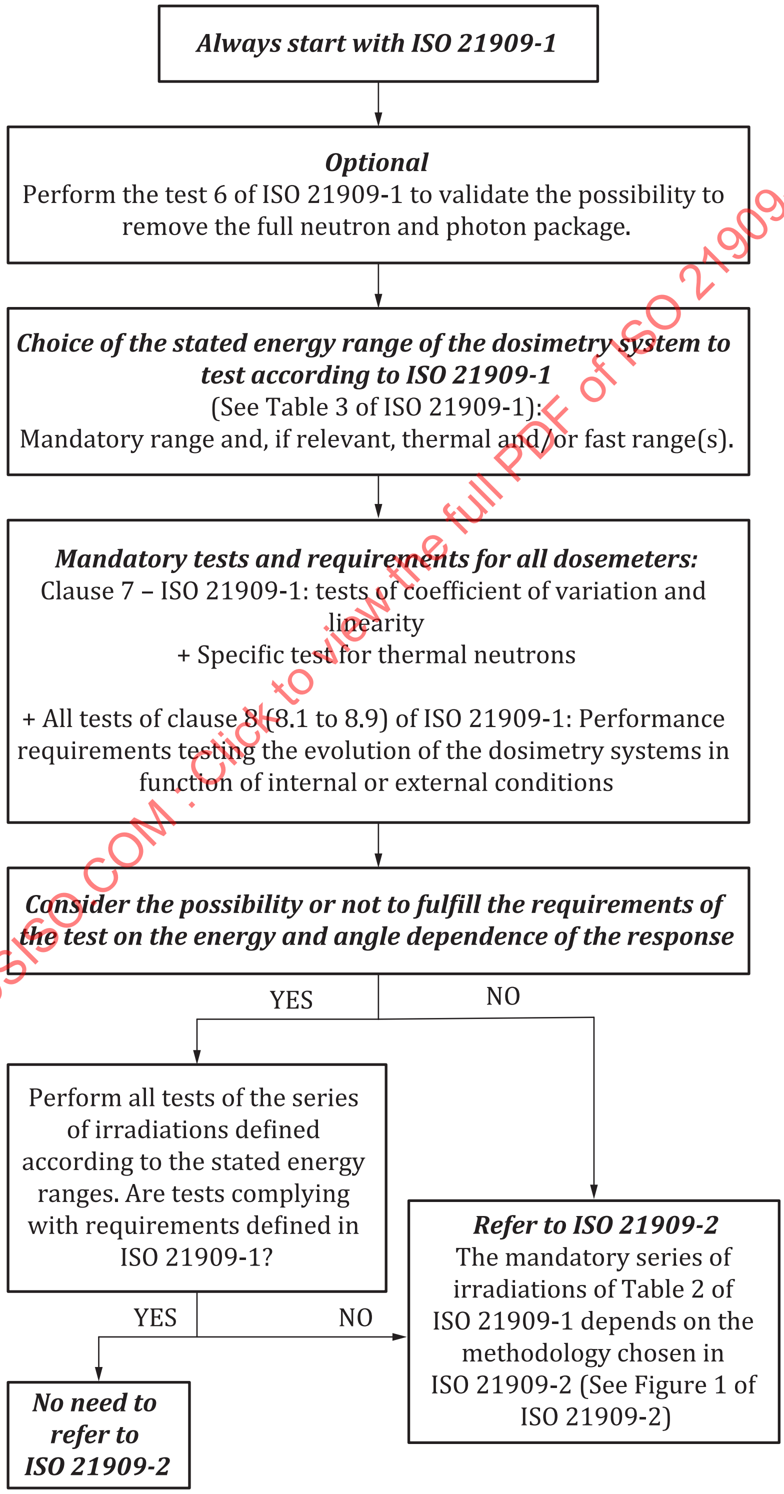
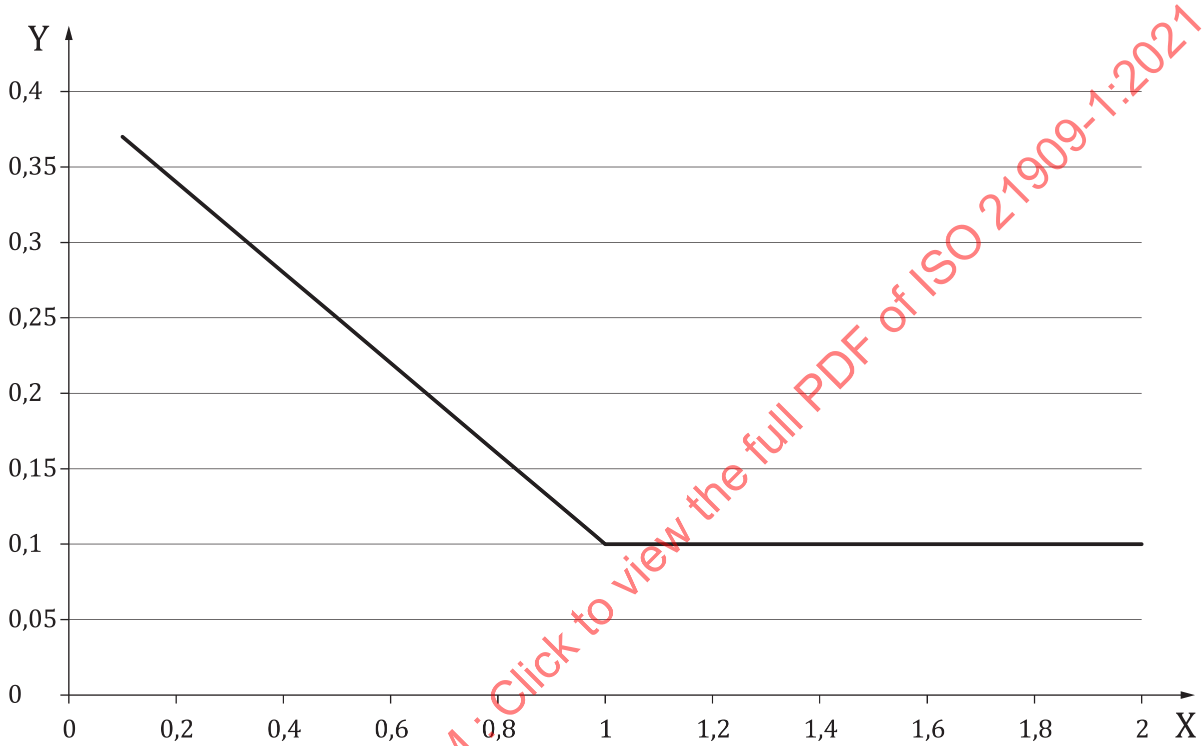


Figure A.1 — Links between this document and ISO 21909-2

Annex B
(normative)

Performance requirements

B.1 Coefficient of variation



Key

X dose equivalent (mSv)

Y criteria for the coefficient of variation test (r_{max})

NOTE The number of dosemeters is fixed as a function of the equivalent dose (see Table B.1).

Figure B.1 — Performance criteria for the coefficient of variation, for all types of dosimetry systems

The equation giving r_{max} represented in Figure B.1 is the following one:

$r_{\text{max}} = 0{,}4 - 0{,}3 \cdot H_{k,j}^{\text{conv}}$ for doses below 1 mSv;

r_{max} = 0,1 for doses equal or higher to 1 mSv.

B.2 Linearity

Table B.1 — Requirements for the linearity performance of the dosimetry systems

No.	Characteristic under test	Personal dose equivalent H_p^{conv} mSv	Number of dosemeters	Performance requirement for the linearity		Types of dosimetry systems and components
				r_{min}	r_{max}	
7.4.3	linearity	0,1	12	−15 %	+18 %	All
		0,2 to 0,4	12			
		0,5	6			
		0,8	6			
		≥ 1	6			

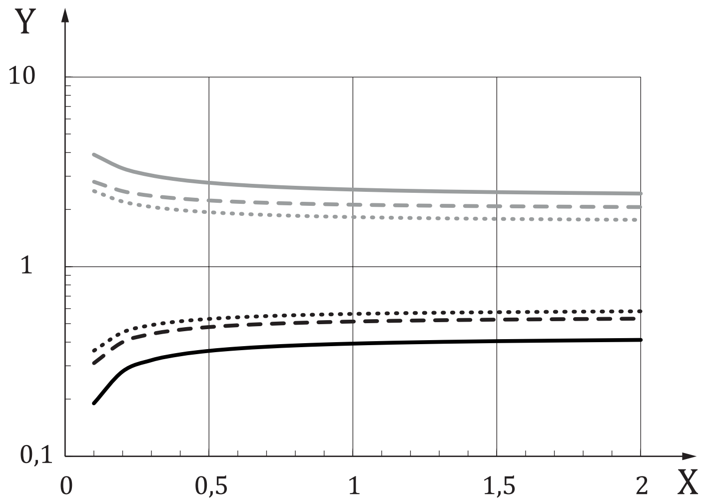
B.3 Energy and angle dependence of the response

Table B.2 — Performance limits as a function of the reference value H^0 and the neutron radiation incidence, for all dosimetry systems

Neutron radiations incidence	r_{min}	r_{max}
0°	$0{,}3\cdot\left(1-\frac{2\cdot H_{low}/1{,}5}{H_{low}/1{,}5+H^0}\right)+0{,}3$	$\left(\frac{2\cdot H_{low}/1{,}5}{H_{low}/1{,}5+H^0}\right)+1{,}7$
30°	$0{,}3\cdot\left(1-\frac{2\cdot H_{low}/1{,}5}{H_{low}/1{,}5+H^0}\right)+0{,}25$	$\left(\frac{2\cdot H_{low}/1{,}5}{H_{low}/1{,}5+H^0}\right)+2$
60°	$0{,}3\cdot\left(1{,}1-\frac{2\cdot H_{low}/1{,}5}{H_{low}/1{,}5+H^0}\right)+0{,}1$	$2\cdot\left(\frac{2\cdot H_{low}/1{,}5}{H_{low}/1{,}5+H^0}\right)+2{,}3$

with H_{low} = 0,1 mSv.

The performance limits, described by these trumpet curves, are illustrated in Figure B.2.



Key

X dose equivalent (mSv)

Y response *R*

r_{min} 0°

r_{max} 0°

r_{min} 30°

r_{max} 30°

r_{min} 60°

r_{max} 60°

Figure B.2 — Performance criteria for the energy and angle dependence of the response, for all types of dosimetry systems

B.4 Stability in the range of realistic conditions of use of the dosemeters

Table B.3 — Performance requirements testing the evolution of the dosimetry systems in function of internal or external conditions

No.	Performance characteristics	Performance requirements	Types of dosimetry systems and components
8.1	Fading (stability of the latent image)	The response of dosimetry systems irradiated at the beginning of a storage period shall not change by more than −15 % +18 % for a storage period under standard test conditions corresponding to the maximal period of storage T_{max}^{fading} between irradiation and read out in the laboratory. The storage period should include the wear period.	All
8.2	Ageing	The response of dosimetry systems irradiated at the end of a storage period shall not vary by more than −15 % +18 % for a storage period T_{max}^{ageing} under standard test conditions. The storage period should include the wear period.	All, but the definition of T_{max}^{ageing} before irradiation storage depends on whether the dosemeters are disposable or reusable.

Table B.3 *(continued)*

No.	Performance characteristics	Performance requirements	Types of dosimetry systems and components
8.3	Effect of storage for unexposed dosemeters	A maximum of 20 % of unirradiated dosemeters present a measured dose equivalent H_M higher than H_{min}. Moreover, no dosemeter shall present a measured dose equivalent H_M higher than H_{min} + 0,1 mSv. If one or more dosemeters present a measured dose equivalent H_M higher than H_{min} + 0,1 mSv, a second test with a lot of 50 dosemeters is necessary: a maximum of one dosemeter shall present a measured dose equivalent H_M higher than H_{min} + 0,1 mSv.	All
8.4	Exposure to radiation other than neutrons: photon radiation	The measured dose equivalent shall not change by more than the value of H_{min} for dosimetry systems exposed to 10 mSv with a ^{137}Cs or ^{60}Co photon source compared to the measured dose equivalent for dosimetry systems which are unirradiated and stored in standard test conditions.	All
		The measured dose equivalent shall not change by more than the value of 0,1 mSv for dosimetry systems exposed to ^{137}Cs or ^{60}Co photon source and to an ^{241}Am-Be or ^{252}Cf neutron source compared to the measured dose equivalent for dosimetry systems exposed to an ^{241}Am-Be or ^{252}Cf neutron source, in the different configurations in terms of ratio: $H^{conv}{}_{neutron}/H^{conv}{}_{photon}$ = 0,3; 1 and 3.	Photon sensitive dosimetry systems
	Exposure to radiation other than neutrons: radon	The measured dose equivalent shall not change by more than 0,5 mSv for dosimetry systems exposed to 3 MBq·h/m³ of radon at 50 % equilibrium with daughters, compared to the measured dose equivalent of dosemeters stored in standard test conditions.	All
8.5	Stability under various climatic conditions: Effect on the dose response	The measured dose equivalent shall not differ from the measured dose equivalent of dosemeters stored in standard test conditions by more than −15 % +18 % for 48 h storage at 40 °C ± 2 °C and 90 % relative humidity when the dosimetry systems are irradiated either at the beginning or at the end of the storage period.	All
	Stability under various climatic conditions: Effect for unexposed dosemeters	A maximum of 20 % of the dosemeters stored for a 48 h period in a climatic chamber in which the temperature is 40 °C ± 2 °C and the relative humidity is at least 90 % shall present a measured dose equivalent higher than H_{min}. Moreover, no dosemeter shall present a measured dose equivalent higher than H_{min} + 0,1 mSv.	
8.6	Effect of light exposure (opacity to light): Effect on the dose response	The measured dose equivalent shall not differ from the measured dose equivalent of dosemeters stored in standard test conditions by more than −15 % +18 % for dosemeters exposed to a xenon lamp equivalent to bright sunlight (295 nm to 769 nm) to 1 000 W/m² for one week.	All
	Effect of light exposure (opacity to light): Effect for unexposed dosemeters	A maximum of 20 % of unirradiated dosemeters exposed to 1 000 W/m² of light for one week presents a measured dose equivalent higher than H_{min}. Moreover, no dosemeter shall present a measured dose equivalent higher than H_{min} + 0,1 mSv.	