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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

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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).

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The committee responsible for this document is ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This first edition of ISO 21909-1 cancels and replaces ISO 21909:2005, which has been technically revised. It also incorporates the Technical Corrigendum ISO 21909-1:2005/Cor:2007.

ISO 21909 consists of the following parts, under the general title *Passive neutron dosimetry systems*:

— *Part 1: Performance and test requirements for personal dosimetry*

This corrected version of ISO 21909-1:2015 includes various editorial corrections and Figure 2 has been modified.

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Introduction

ISO 21909-1 gives 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 an 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) packed together, incorporating some means of identification;

c) treatment to prepare the dosemeter before irradiation and/or before reading;

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

This part of ISO 21909 aims at covering all passive neutron detectors that can be used as a personal dosemeter in part or in all of the above-mentioned neutron energy range. This part of ISO 21909 does not focus on any technique in particular, but intends to be general, including when new techniques emerge. When distinctions are necessary, they are defined in as generic way as possible: disposable/reusable dosemeters and photon-sensitive dosemeters. In conclusion, no performance tests are dedicated to one particular technique, unless it is absolutely necessary, in order for this part of ISO 21909 to reach a global coherence between the different available techniques. Consequently, this part of ISO 21909 aims to define performance tests leading to similar results independent of the techniques used.

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The main objective of this part of ISO 21909 is to achieve correspondence between performance tests and conditions of use at workplaces. Dosimetry systems complying with this part of ISO 21909 are wanted to give consistent annual dosimetry in standard workplace environments. Reaching such an objective means that this part of ISO 21909 takes into account the various situations of exposure in terms of dose levels and neutron energy distributions.

Annual exposures of many workers usually consist of the sum of several low doses close to the minimal recording value. The dosemeter needs therefore to be well characterized, not only for relatively high dose measurement but also for low doses, to make sure the annual dose is given with an adequate uncertainty. In this part of ISO 21909, there is no description of test aiming at determining the detection threshold by measuring the background signal of the dosemeter when it is not irradiated. But all the tests aiming at characterizing the dosimetric performance of the system (coefficient of variation and linearity, energy and angular responses) are required at two levels of dose: around 1 mSv and close to the minimal 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.

In other words, the main goal of this part of ISO 21909 is to ensure that a dosemeter is reliable enough 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 mean energies of the dose equivalent distributions of the most common reference radiations (e.g. ^{241}Am-Be or ^{252}Cf neutron sources) as used for calibration are generally higher than the ones encountered in workplaces. The performance of the dosemeters for energies situated between a few tens and a few hundreds of keV needs notably 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 part of ISO 21909.

For the performance tests aiming at characterizing 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, and sealing), it is considered to be sufficient to use only one neutron source (e.g. ^{241}Am-Be or ^{252}Cf neutron sources).

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This part of ISO 21909 does not present performance tests aiming at 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.

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.

Moreover, to deal with dosimetry systems whose energy and direction dependences of response do not fulfil all the requirements of this part of ISO 21909, another document would be needed to complete this part of ISO 21909, giving complementary specific recommendations. In this case, a study at the workplace where the dosemeters are used is necessary to complete all the tests performed according to this part of ISO 21909. This new part would give recommendations to qualify the dosimetry system at the workplace, giving a methodology. Even when the dosimetry system fulfils the requirements of this part of ISO 21909, it may still be desirable to make a similar study at the workplace (this will be the subject of a future part of ISO 21909.

This part of ISO 21909 also needs to be extended in the future to another part for the ambient dose equivalent $H^*(10)$ for ambient and environmental dosimetry.

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Passive neutron dosimetry systems —

Part 1: Performance and test requirements for personal dosimetry

1 Scope

This part of ISO 21909 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)]. No distinction between the different techniques available in the market place is made in the description of the tests. Only generic distinctions, as disposable or reusable dosemeters for instance, are considered. This part of ISO 21909 gives information for extremity dosimetry, based on recommendations given by ICRU Report 66 in Annex A.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 8529-1:2001, *Reference neutron radiations — Part 1: Characteristics and methods of production*

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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*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms, definitions, and symbols

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

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]

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. The present standard 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.

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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
dosemeter worn by a person for determining the personal dose equivalent received

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[SOURCE: IEC 60050-394:2007, 394-31-11 modified — Notes 1 and 2 were removed.]

3.2 Terms relating to quantities

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3.2.1
absorbed dose
D
quotient of $d\bar{\varepsilon}$ by dm, where $d\bar{\varepsilon}$ is the mean energy imparted to matter of mass dm thus

$$D = \frac{d\bar{\varepsilon}}{dm}$$

Note 1 to entry: The unit of absorbed dose is joule per kilogram ($J \cdot kg^{-1}$). The special name for the unit of absorbed dose is Gray (Gy).

[SOURCE: ICRU 60, 4.2.5]

3.2.2
quality factor
Q
number by which the *absorbed dose* (3.2.1) (*D*) is multiplied to reflect the relative biological effectiveness of the radiation, the result being the *dose equivalent* (3.2.3)

[SOURCE: ISO 12749-2:2013, 4.1.6.6]

3.2.3
dose equivalent
H
product of *D* and *Q* at a point in tissue, where *D* is the *absorbed dose* (3.2.1) and *Q* is the *quality factor* (3.2.2) for the specific radiation at this point, thus

$$H = D \cdot Q$$

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

[SOURCE: ICRP 103:2007]

3.2.4
ICRU sphere
sphere of 30 cm diameter made of tissue equivalent material with a density of 1 g/cm^3 and a mass composition of 76,2 % oxygen, 11,1 % carbon, 10,1 % hydrogen, and 2,6 % nitrogen

[SOURCE: ISO 12749-2:2013, 4.1.6.4, modified]

3.2.5
fluence
quotient of dN divided by da, where dN is the number of incident particles on a sphere of cross-sectional area da

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

[SOURCE: ISO 8529-1:2001, modified]

3.2.6
personal dose equivalent
$H_p(d)$
dose equivalent (3.2.3) in soft tissue at an appropriate depth, d, below a specified point where the dosemeter is worn/mounted, i.e. on the human body or a calibration phantom

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

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

[SOURCE: ISO 12749-2:2013, 4.1.6.8.3, modified]

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3.2.7
conversion coefficient
$h_{p\Phi}(d,E,\alpha)$
quotient of the personal dose equivalent, $H_p(d)$, and the neutron fluence, Φ, at a point in the radiation field used to convert neutron fluence into the personal dose equivalent at d 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 $Sv \cdot m^2$. A commonly used unit of the conversion coefficient is $pSv \cdot cm^2$.

3.3 Terms relating to calibration and evaluation

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

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

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3.3.2
conventional quantity value
H^0
quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: The conventional value H^0 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.

[SOURCE: ISO/IEC Guide 99:2007, 2.12, 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 indications 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.

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

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3.3.4
calibration factor
N

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quotient of the *conventional quantity value* (3.3.2), H^0, divided by the *reading*, *M* (3.3.15), derived under standard conditions, given by the following formula:

$$N = \frac{H^0}{M}$$

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

Note 1 to entry: For the purpose of this part of ISO 21909, the calibration quantity is the personal dose equivalent at 10 mm depth in the ICRU tissue slab phantom, $H_p(10)$.

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

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

where

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

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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:

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

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

3.3.8
detection threshold
minimum measured dose equivalent which is significantly higher (at the 95 % confidence level) than the mean dose equivalent of a sample of unirradiated dosemeters

3.3.9
minimal recording value
$H_{\min}$
minimal value of dose which is recorded, i.e the lower limit of the dose range, defined by the dosimetry laboratory

Note 1 to entry: $H_{\min}$ would be logically at least equal or lower to the legal threshold of the country. Depending on the country or the dosimetry laboratory, $H_{\min}$ is different: 0,10; 0,20 or 0,30 mSv, for example.

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Note 2 to entry: In this part of ISO 21909, $H_{\min}$ shall be equal to 0,3 mSv at maximum: $H_{\min} \leq 0{,}3$ mSv.

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3.3.10
in-field calibration
procedure to calibrate neutron dosemeters in neutron fields representative of a working environment for which the personal dose equivalent rates or neutron spectra and angle distributions have been determined by appropriate methods and hence are sufficiently well known

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3.3.11
influence quantity
quantity (parameter) that may have a bearing on the results of a measurement without being the objective of the measurement

[SOURCE: ISO 8529-3:1998, 3.2.1, modified]

3.3.12
measured dose equivalent
H^{M}
product of the reading, M, and the calibration factor, N:

$$H^{\mathrm{M}} = M \cdot N$$

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

3.3.13
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.

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