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Sistemi pasivne nevtronske dozimetrije - 2. del: Metodologija in merila za kvalifikacijo osebnih dozimetričnih sistemov na delovnih mestih (ISO 21909-2:2021)

Passive neutron dosimetry systems - Part 2: Methodology and criteria for the qualification of personal dosimetry systems in workplaces (ISO 21909-2:2021)

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Systèmes dosimétriques passifs pour les neutrons - Partie 2: Méthodologie et critères de qualification des systèmes dosimétriques individuels aux postes de travail (ISO 21909-2:2021)

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

iTeh STANDARD PREVIEW

Systèmes dosimétriques passifs pour les neutrons —

*Partie 2: Méthodologie et critères de qualification des systèmes
dosimétriques individuels aux postes de travail*

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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).

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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*.

A list of all the 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

ISO 21909-1 provides laboratory-based type tests, and performance requirements for passive neutron dosimetry systems to be used for measurement of personal dose equivalent, $H_p(10)$, for neutrons ranging from thermal energy to approximately 20 MeV^[1]. No distinction between the different techniques available in the marketplace is made in the description of the tests. ISO 21909 (series) aims at covering all passive neutron detectors that can be used as a personal dosimeter in parts of, or in the complete above-mentioned neutron energy range.

The main objective of ISO 21909 series is to achieve correspondence between performance tests and conditions of use at the workplaces. Dosimetry systems complying totally with ISO 21909-1 should give consistent dosimetry results in workplace environments without the requirement of precise information on the characteristics of the radiation fields (neutron energy and direction distributions).

For the case that a dosimetry system does not comply with the full range of requirements in ISO 21909-1 with regard to the dependence of the response on the energy and direction distributions of the neutron fluence, it remains necessary to evaluate the performance of the dosimetry system for the conditions of the workplace. That means that this document is systematically used to qualify at workplaces a dosimetry system that does not fulfil the criteria of ISO 21909-1 on the dependence of the response on neutron energy and direction of incidence.

This document aims to address dosimetry systems with responses that show energy and directional dependencies that do not comply with the test requirements in ISO 21909-1, but that are able to give consistent and reliable dosimetry results at selected workplaces. In this case, a specific study of the workplace where the dosimetry systems are used is necessary to demonstrate that the dosimetry systems are suited for the workplace of application and, if needed, to determine the appropriate corrections to be applied. This document gives requirements for the qualification of the dosimetry system as well as methods for evaluating its performance and qualifying it for use in the workplace.

In cases where the dosimetry system meets the requirements of ISO 21909-1, it may still be desirable to perform a similar study at the workplace to improve the performance of the neutron dosimeters. It is also recommended that this document may be implemented, not only for passive dosimetry systems, but for active dosimetry systems as well.

No qualification or correction of the dosimetry system at a workplace is required if the dosimetry system fulfils the criteria of ISO 21909-1.

All the estimations of the uncertainties in this document have to be considered in accordance with the GUM^[2]. Uncertainties quoted in this document are provided using a coverage factor $k=2$.

Passive neutron dosimetry systems —

Part 2:

Methodology and criteria for the qualification of personal dosimetry systems in workplaces

1 Scope

This document provides methodology and criteria to qualify the dosimetry system at workplaces where it is used. The criteria in this document apply to dosimetry systems which do not meet the criteria with regard to energy and direction dependent responses described in ISO 21909-1.

The qualification of the dosimetry system at workplace aims to demonstrate that:

- either, the non-conformity of the dosimetry system to some of the requirements on the energy or direction dependent responses defined in ISO 21909-1 does not lead to significant discrepancies in the dose determination for a certain workplace field;
- or, that the correction factor or function used for this specific studied workplace enables the dosimetry system to accurately determine the conventional dose value with uncertainties similar to the ones given in ISO 21909-1.

NOTE This document is directed at all stakeholders who are involved: IMSs, accreditation or regulatory bodies, and users of the particular dosimetry (the user is meant as the entity which assigns the dosimetry system to the radiation worker and records the assigned dose.)

The methodologies to characterize the work place field in order to perform the qualification of the dosimetry system are given in [Annex A](#). [Annex B](#) is complementary as it gives the practical methods to follow, once one methodology is chosen.

The provider of the dosimetry system shall provide the type test results corresponding to ISO 21909-1. However, when the dosimetry system to be qualified does not comply with all the criteria of ISO 21909-1 dealing with the energy and angle dependence of the response, some tests of the ISO 21909-1 can be not performed.

The links between ISO 21909-1 and ISO 21909-2 are described in [Annex E](#).

This document only addresses neutron personal monitoring and not criticality accident conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitute 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 21909-1:2021, *Passive neutron dosimetry systems — Part 1: Performance and test requirements for personal dosimetry*

ISO 8529-2:2000, *Reference neutron radiations — Part 2: Calibration fundamentals of radiation protection devices related to the basic quantities characterizing the radiation field*

ISO 8529-3:1998, *Reference neutron radiations — Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence*

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3 Terms, definitions and symbols

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 <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 General terms and definitions

3.1.1

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]

3.1.2

dosemeter

dosimeter

device having a reproducible, measurable response to radiation that can be used to measure the absorbed dose or dose equivalent quantities in a given system

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

3.1.3

personal dosimeter

meter designed to measure the personal dose equivalent (rate)

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

[SOURCE: ISO 29661:2012, 3.1.21]

3.1.4

individual monitoring service

IMS

organization that operates a personal-dosimetry system which includes the evaluation of the reading of dosimeters after their use and may include:

- providing the user with dosimeters;
- recording the results;
- reporting the results to the user

3.1.5

dosimetry system

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

[SOURCE: ISO 12749-4:2015, 3.1.3, modified — the wording of the definition was slightly modified.]

3.2 Quantities

3.2.1

dose equivalent

H

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

$$H = DQ$$

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

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

3.2.2

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 :

$$\Phi = \frac{dN}{da}$$

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 — the wording of the definition was slightly modified.]

3.2.3

energy distribution of the neutron fluence

Φ_E

quotient of $d\Phi$ by dE , where $d\Phi$ is the fluence of neutrons with energy between E and $E + dE$

$$\Phi_E = \frac{d\Phi}{dE}$$

Note 1 to entry: The SI unit of the energy distribution of the neutron fluence is ($\text{m}^{-2}\cdot\text{J}^{-1}$); a widely-used unit is ($\text{cm}^{-2}\cdot\text{MeV}^{-1}$).

Note 2 to entry: The energy distribution of the neutron fluence rate ϕ_E is the quotient of $d\Phi_E$ by dt , where $d\Phi_E$ is the increment of the energy distribution of the fluence in time interval dt . The unit is ($\text{m}^{-2}\cdot\text{J}^{-1}\cdot\text{s}^{-1}$); a widely-used unit is ($\text{cm}^{-2}\cdot\text{MeV}^{-1}\cdot\text{s}^{-1}$).

3.2.4

energy and direction distribution of the neutron fluence

$\Phi_{E,\Omega}$

quotient of $d\Phi$ by dE and $d\Omega$, where $d\Phi$ is the *fluence* of neutrons with energy between E and $E + dE$ and propagating within a solid angle $d\Omega$ around a specified direction, Ω , expressed as

$$\Phi_{E,\Omega} = \frac{d^2\Phi}{dE d\Omega}$$

Note 1 to entry: The SI unit of the energy and direction distribution of the neutron fluence is $\text{m}^{-2}\cdot\text{J}^{-1}\cdot\text{sr}^{-1}$; a widely-used unit is ($\text{cm}^{-2}\cdot\text{MeV}^{-1}\cdot\text{sr}^{-1}$).

Note 2 to entry: The energy and direction distribution of the neutron fluence rate $\phi_{E,\Omega}$ is the quotient of $d\Phi_{E,\Omega}$ by dt , where $d\Phi_{E,\Omega}$ is the increment of the energy and direction distribution of the fluence in time interval dt . The unit is ($\text{m}^{-2}\cdot\text{J}^{-1}\cdot\text{sr}^{-1}\cdot\text{s}^{-1}$); a widely-used unit is ($\text{cm}^{-2}\cdot\text{MeV}^{-1}\cdot\text{sr}^{-1}\cdot\text{s}^{-1}$).

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3.2.5

personal dose equivalent $H_p(d)$

dose equivalent 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 ($\text{J}\cdot\text{kg}^{-1}$) 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 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 at 10 mm depth, $H_p(10)$, and the *neutron fluence*, Φ , 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 $\text{Sv}\cdot\text{m}^2$. A commonly used unit of the conversion coefficient is $\text{pSv}\cdot\text{cm}^2$.

3.3 Calibration and evaluation

3.3.1

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 — the term was changed.]

3.3.2

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]

3.3.3 calibration factor

N

quotient of the *conventional quantity value*, H^{conv} , (3.3.1) divided by the reading, M , derived under standard test conditions, given by the formula:

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

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.

3.3.4 correction factor or function

numerical value or function by which the indication is multiplied to compensate for the deviation of measurement conditions from reference conditions or for a systematic effect

Note 1 to entry: In this document, it corresponds to the factor or function, noted $k_{n,E,\Omega}$, defined for a specific workplace field, that is applied to the value of the measured dose equivalent in order to take into account the systematic effect induced by the dose response of the dosimetry system.

[SOURCE: ISO 29661:2012, 3.1.9, modified — the wording of the definition was slightly modified.]

3.3.5 measured dose equivalent

H_M

product of the reading, M , and the calibration factor, N :

$$H_M = M \cdot N$$

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

Note 2 to entry: This definition is only valid for a calibration field. To extend it to any other field, the correction factor of function $k_{n,E,\Omega}$ needs to be added. In that case, the formula becomes:

$$H_M = M \cdot N \cdot k_{n,E,\Omega}$$

3.3.6 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 x 30 cm x 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: 2013, 4.1.6.1 modified — Notes 1 and 2 to entry added]

3.3.7 reading

M

quantitative indication of a detector or dosimeter when it is read out, generally corrected for background, ageing, fading and non-linearity of the process or the read out system