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Passive personal neutron dosemeters — Performance and test requirements

Dosimètres individuels passifs pour les neutrons — Exigences de fonctionnement et d'essai

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Foreword

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ISO 21909 was prepared by Technical Committee ISO/TC 85*, Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

Introduction

ISO 21909 contains performance and test requirements for dosemeters to be used for the determination of personal dose equivalent, $H_p(10)$, in neutron fields with energies ranging from thermal to 20 MeV. In this energy range, reference neutron radiation are reported in ISO 8529-3. Reference radiation are required for the proper calibration of the dosemeters. This International Standard covers the following five classes of passive neutron detectors that can be used as a personal dosemeter in part or all of the above-mentioned neutron energy range:

— nuclear track emulsion dosemeters (NTED);

— solid state nuclear track dosemeters (SSNTD);

— thermoluminescence albedo dosemeters (TLAD);

— superheated emulsion dosemeters (SED);

— ionization chamber dosemeters (ICD).

Passive personal neutron dosemeters — Performance and test requirements

1 Scope

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

2 Normative references

The following referenced documents are indispensable for the application 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 5-2:2001, *Photography — Density measurements — Part 2: Geometric conditions for transmission density*

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

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 — Calibration of area and personal dosemeters and determination of response as a function of energy and angle of incidence*

ISO 12789:2000, *Reference neutron radiations — Characteristics and methods of production of simulated workplace neutron fields*

3 Terms and definitions

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

3.1 General terms

3.1.1
ageing
changes occurring in an unirradiated dosemeter with time

3.1.2
batch
⟨detectors or dosemeters⟩ grouping of detectors or dosemeters manufactured according to the same specification and usually at the same time

NOTE 1 Detectors from a batch are intended and supposed to have the same performance characteristics, consistent with the appropriate requirements of this International Standard, and to be used in type or quality test procedures.

NOTE 2 In the case of SSNTD, a batch under this definition can be as small as one single sheet.

3.1.3
detector
device or substance that indicates the presence of a phenomenon without necessarily providing a value of an associated quantity

NOTE In particular, in the presence of radiation, such devices or substances provide by either a direct or indirect means a signal or other indication suitable for measuring one or more quantities.

3.1.4
fading
changes occurring in an irradiated dosemeter with time

3.1.5
personal dosemeter
device comprising one or more detectors positioned in a holder, suitable for the measurement of personal dose equivalent

3.2 Quantities

3.2.1
absorbed dose
D
$\mathrm{d}\bar{\varepsilon}$ divided by dm, where $\mathrm{d}\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter with mass dm

NOTE 1 The SI unit of absorbed dose is the J/kg. The special name for the unit of absorbed dose is gray (Gy)[20].

NOTE 2 In quoting values of absorbed dose, it is necessary to specify the material. e.g. soft tissue.

3.2.2
ambient dose equivalent
$H^*(d)$

dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned field in the ICRU sphere at a depth, d, on the radius opposing the direction of the aligned field

NOTE 1 The SI unit of ambient dose equivalent is J/kg. The special name for the unit of ambient dose equivalent is sievert (Sv).

NOTE 2 For strongly penetrating radiation, a depth of 10 mm is currently recommended. The ambient dose equivalent for this depth is then denoted by $H^*(10)$[20].

3.2.3
dose equivalent
H
product of Q and D at a point in soft tissue, where D is the absorbed dose and Q is the quality factor at that point

NOTE The SI unit of dose equivalent is J/kg. The special name for the unit of dose equivalent is sievert (Sv)[20].

3.2.4
neutron fluence
Φ_n
dN divided by da, where dN is the number of neutrons incident on a sphere of cross-sectional area da

NOTE The SI unit of neutron fluence is m^{-2}, a frequently unit used is cm^{-2} (ISO 8529-1).

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

NOTE 1 The SI unit of personal dose equivalent is J/kg. The special name for the unit of personal dose equivalent is sievert (Sv)[20].

NOTE 2 Soft tissue in this context is the ICRU 4-element tissue.

3.2.6
conversion coefficient
$h_{p\Phi}(10;E,\alpha)$
quotient of the personal dose equivalent, $H_p(10)$, and the neutron fluence, Φ_n, at a point in the radiation field and used to convert from 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 The SI 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
$\bar{x}$
average of a series of n measurements, x_i, given by the equation

$$\bar{x} = (1/n)\sum_{i=1}^{n} x_i$$

3.3.2
calibration
set of operations which establish, under a controlled set of standard test conditions, the relationship between the reading given by a dosemeter and the quantity to be measured

3.3.3
calibration factor
N
quotient of the conventional true value, H_t, divided by the reading, M (see 3.3.16), derived under standard conditions, given by the equation

$$N = \frac{H_t}{M}$$

3.3.4
calibration quantity
physical quantity used to establish the calibration of the dosemeter

NOTE For the purpose of this International Standard, the calibration quantity is the personal dose equivalent at 10 mm depth in the ICRU tissue slab phantom, $H_p(10)$.

3.3.5
coefficient of variation
V
measure of dispersion for a series of n measurements, x_i, given by the equation

$$V = s/\bar{x}$$

where s is the experimental standard deviation and $\bar{x}$, the arithmetic mean of n measurements.

3.3.6
control specimens
lot of reference detectors or dosemeters of the same type and batch as those used in the test procedures

3.3.7
conventional true value of a quantity
H_t
⟨dose equivalent⟩ best estimate of a value of a quantity, as determined by a primary or secondary standard or by a reference instrument that has been calibrated against a primary or secondary standard

NOTE A *conventional true value* is regarded as being sufficiently close to the *true value* such that the difference is considered as insignificant for the given purpose.

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

3.3.9
experimental standard deviation
s
parameter for a series of n measurements, x_i, characterizing the dispersion and given by the equation

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

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

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 neuton spectra and angle distributions have been determined by appropriate methods and hence are sufficiently well known

3.3.11
influence quantity
quantity (parameter) that can have a bearing on the results of a measurement without being the objective of the measurement (ISO 8529-3)

3.3.12
measured dose equivalent
H_M
product of the reading, M, and the calibration factor, N

$$H_M = M \cdot N$$

NOTE In the case of TLAD, elaborate algorithms are generally required (see E.3).

3.3.13
phantom
specified object used to simulate the human body or parts thereof in terms of scattering and absorption properties

NOTE For calibrations, the ISO water slab phantom is employed. It is made with polymethylmetaacrylate (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.

3.3.14
quality test
QT
test performed on a number of detectors or dosemeters of a given batch or production designed to assure their quality

NOTE These tests are usually carried out by the user.

3.3.15
read out
process of determining the indication of a detector or dosemeter reader

NOTE For the NTEDs and SSNTs, the reading is usually the number of tracks recorded per unit area; for TLADs, it is the integrated current from the reader; for SEDs, it is the number of bubbles detected or the change in volume; and for ICDs, it is the electric charge collected.

3.3.16
reading
M
quantitative indication of a detector or dosemeter when it is read out, generally corrected for background, ageing, fading and non-linearity of the process or the read out system

3.3.17
reference conditions
set of influence quantities for which the calibration factor is valid without any correction (ISO 8529-3)

3.3.18
response
R
measured dose equivalent, H_M, divided by the conventional true value of the dose equivalent, H_t (see 3.3.7), as given by the following equation

$$R = \frac{H_M}{H_t}$$

NOTE 1 The reading, M, is converted into dose equivalent, H_M, by multiplying M by an appropriate conversion coefficient. In the case of TLAD, elaborate algorithms are generally required (see E.3).

NOTE 2 In this International Standard, the quantity is personal dose equivalent: $R = H_{p,M}(10)/H_{p,t}(10)$.

NOTE 3 In this International Standard for the sake of shortness, $H_M = H$ will be used in Annex C.

NOTE 4 For the specified reference conditions, the response is the reciprocal of the calibration factor.

NOTE 5 In radiation metrology, the term response, abbreviated for this application from "response characteristic"[15] 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 (ISO 8529-3).

3.3.19
standard test conditions
range of values of a set of influence quantities under which a calibration or a determination of response is carried out

3.3.20
type test
TT
performance test of one or more devices that are made to a certain design to show that the design meets given specifications

3.4 Terms with respect to nuclear track emulsion dosemeters (NTED)

3.4.1
film packet
ensemble containing the emulsion wrapped in a light tight envelope that is placed in a sealed pouch, generally filled with dry nitrogen or air, meant to protect the emulsion against fading

3.4.2
latent image
invisible change occurring within the photographic emulsion when it is exposed to actinic radiation, i.e. visible light, ultraviolet or radiation that is directly or indirectly ionizing and that will be converted upon processing into a visible image like a nuclear track

3.4.3
nuclear tracks
tracks created in a nuclear emulsion following the interaction of neutrons with the nuclei in the emulsion, base, wrapping and holder giving rise to protons [by $^{14}N(n,p)^{14}C$] or recoil nuclei

3.4.4
nuclear track emulsion
photographic emulsion capable of recording nuclear tracks in a latent form

NOTE These tracks become visible after the chemical development and can be counted under a microscope or any other appropriate scanning device.

3.4.5
nuclear track emulsion dosemeter
passive device consisting of a film packet mounted in a holder (appropriate for the application), intended to be worn on a person's body, detecting neutrons for the purpose of assessing the appropriate personal dose equivalent at or near the position where it is placed

3.4.6
optical density
S
logarithm to the base 10 of the ratio of aperture flux [ISO 5-2] to the flux transmitted by the sample under the same beam geometric conditions

3.4.7
scanning
process of evaluating a nuclear track emulsion by counting the visible tracks under a microscope either by an operator or by an automatic scanning device

3.4.8
stability of latent image
degree to which a nuclear track emulsion is capable of producing a developed image of a nuclear interaction irrespective of the time elapsed between the formation of the latent image and the development of the emulsion and irrespective of the ambient conditions that have prevailed during this time (temperature or humidity)

3.4.9
track density
number of tracks scanned per unit area

3.5 Terms with respect to solid state nuclear track dosemeters (SSNTD)

3.5.1
chemical etch bath
configuration containing the etching solution for etching detectors under a defined temperature

3.5.2
converter material
material in which neutrons undergo nuclear reactions and produce charged particles that can be detected by SSNT

NOTE Examples are hydrogen compounds for fast neutrons, and ^{10}B, ^{6}Li or nitrogen-containing compounds for thermal and epithermal neutrons.

3.5.3
etch chamber
device containing the detectors in a geometry allowing their proper etching under defined temperature conditions and an applied voltage (if applicable)

3.5.4
etching
process to develop the radiation induced tracks in detectors to make them countable

NOTE Etching could be chemical by putting the detectors into a proper chemical solution under defined temperature conditions. When an alternating high voltage is applied across the detector, then etching is called electro-chemical.

3.5.5
solid state nuclear track dosemeter
passive device consisting of one or more track etch detectors mounted in a holder (appropriate for the application), intended to be worn on a person's body to detect neutrons for the purpose of assessing the appropriate personal dose equivalent at or near the position where it is placed

3.5.6
track etch detector
material, usually plastic in nature, carefully manufactured under controlled conditions for the purpose of radiation measurements

3.5.7
track etch reader
device used to establish the number of tracks per unit area

3.6 Terms with respect to thermoluminescence albedo dosemeters (TLAD)

3.6.1
albedo
fraction of incident radiation scattered from a surface

NOTE Neutrons scattered back from a body following interactions within the body are called albedo neutrons.

3.6.2
annealing
controlled thermal treatment of a TL detector or dosemeter during or after readout

3.6.3
apparent photon dose equivalent
H_a
measured dose equivalent of each detector evaluated as if it had been irradiated by reference photon radiation

3.6.4
preparation
normal treatment of annealing, cleaning, etc., of detectors or dosemeters that are intended for routine use

3.6.5
thermoluminescence
TL
emission of light exhibited by certain substances or materials when the substance is heated following its exposure to ionizing radiation or U.V.

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

3.6.6
thermoluminescence albedo neutron dosemeter
albedo dosemeter
passive device, consisting of two or more TL detectors, mounted in a holder (appropriate for the application), intended to detect incident and albedo neutrons when worn on a person's body for the purpose of assessing the appropriate personal dose equivalent at or near the position where it is placed

3.6.7
thermoluminescent detector
specified quantity of TL material, or such material incorporated with other non-luminescent material into a matrix, being defined by mass, shape or size or the mass of material incorporated in the matrix

3.6.8

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

3.6.9
zero point
reading of unirradiated TLDs expressed in apparent photon dose equivalent

3.7 Terms with respect to superheated emulsion dosemeters (SED)

3.7.1
activation
procedure to render superheated emulsions ready for use

NOTE 1 Bubble detectors (BD) are typically stored and kept inactive under pressure, which is applied keeping their screw caps on. They are activated by removing the screw cap.

NOTE 2 Superheated drop detectors (SDD) are typically stored and kept inactive at reduced temperature. They are activated by allowing them to reach ambient temperature.

3.7.2
bubble reading
reading of a dosemeter based on superheated emulsions

NOTE In bubble detectors (BD), the number of visible bubbles, that comprise the measurement, is obtained by optical counting or by use of an automatic electro-optical instrument. In the superheated drop detectors, the volume of evolved gas is measured with the help of a calibrated scale.

3.7.3
depletion
decrease in the number of superheated drops due to their transformation into bubbles after being struck by neutrons

NOTE In the bubble detectors (BD), the initial sensitivity is restored by repressurization and no depletion correction is necessary. In the superheated drop detectors, the bubbles separate permanently from the detector and a depletion correction is necessary with prolonged use.

3.7.4
resetting
clearing of bubbles from the visco-elastic matrix

NOTE In the bubble detectors (BD), this is done by the application of external pressure using a piston assembly. In the superheated drop detectors, resetting is unnecessary because the bubbles leave the medium by rising to the top of the dosemeter due to their buoyancy.

3.7.5
superheated drops
drops of superheated liquid, generally of 5 µm to 100 µm diameter

NOTE These drops dispersed throughout a visco-elastic matrix represent the radiation-sensitive sites of the detector.

3.7.6
superheated emulsion
SE
superheated drops dispersed within a clear visco-elastic matrix

NOTE Superheated emulsions are typically contained in a device consisting of a transparent, cylindrical holder. Visible bubbles are formed throughout the device when irradiated with neutrons. The number of bubbles provides a measure of the neutron dose.

3.7.7
superheated liquid
fluid above its normal boiling point that is still in the liquid phase

3.7.8
visco-elastic matrix
⟨gel⟩ aqueous or polymer gel in which immiscible superheated drops are uniformly emulsified

NOTE In bubble detectors, the visco-elastic matrix typically keeps bubbles immobilized at the location of their formation. In superheated drop detectors (SDD), the visco-elastic matrix typically allows bubbles to rise out of the detector by buoyancy.

3.8 Terms with respect to ion chamber dosemeters with direct ion storage (ICD)

3.8.1
apparent photon dose equivalent
H_a
measured dose equivalent of each detector evaluated as if it had been irradiated by reference photon radiation

3.8.2
direct ion storage
DIS
permanent storage of an electric charge in a MOSFET with an open floating gate connected to an ion chamber

3.8.3
ion chamber detector
air volume surrounded by conductive wall material with applied electric field to collect ions produced by ionizing radiation

NOTE The neutron sensitivity of an ion chamber strongly depends on the wall material. Pairs of ion chambers with different neutron sensitivities are used to differentiate between neutron and photon radiation.